Water spectrum

SPRING 1980

Water spectrum

Published Quarterly | Vol. 12, No. 2 | Spring 1980

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Editor, Water Spectrum
U.S. Army Corps of Engineers
Water Resources Support Center (WRSC)
Fort Belvoir, VA. 22060
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Use of funds for printing this quarterly publication was approved by the Director of the Office of Management and Budget through June 30, 1982.

A major purpose of this publication is to serve as a written forum for the open discussion of issues and choices in resolving water resource problems. Views and conclusions expressed or implied do not necessarily reflect the position of the Corps of Engineers.

Subscription rate is $5.50 per year; $1.40 additional for foreign mailing. Price of a single copy is $1.40. Order directly from Superintendent of Documents, Government Printing Office, Washington, D.C. 20402.

This issue developed by Publications & Training Office, WRSC

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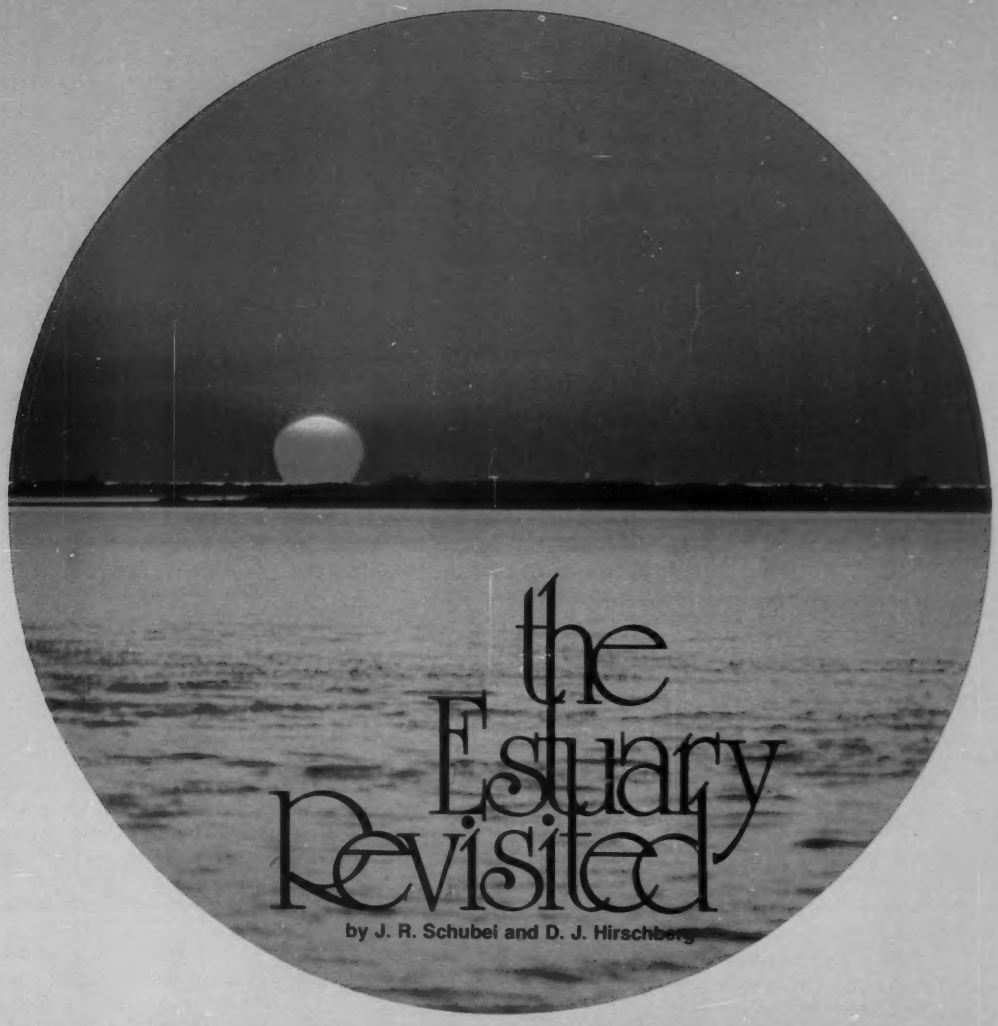
COVER: *"From you have I been absent in the spring*
When proud-pied April, dress'd in all his trim
Hath put a spirit of youth in everything."–Shakespeare

(Photo by Bruce Berg)



the Estuary Revisited

by J. R. Schubel and D. J. Hirschberg

Sunset on the Atchafalaya Estuary. (Photo by J. Parker)

Editor's Note: In 1977, the authors presented a paper entitled "Estuarine Graveyards, Climatic Change, and the Importance of the Estuarine Environment" at the Fourth International Estuarine Research Federation Conference. The paper was subsequently published in Estuarine Interactions *(M. L. Wiley, ed., 1978). The authors received a respectable number of reprint requests, but no controversy resulted. Then, the* New York Times, *in its Sunday, March 11, 1979, edition, featured an article on the paper headlined: "Researchers Assert Estuaries, While Undoubtedly Beneficial, Are Not Vital To Marine and Human Life." Had it not been the Sunday Times, or if the headline wording had been less inflammatory, the original presentation might have remained quietly within its own scientific limbo. But within weeks the authors were deluged with telephone calls—equally supportive and antagonistic—and requests for reprints.*

In July 1979, Water Spectrum *solicited the following article on this controversial study. The study findings represent an intensive review of the literature in the estuarine study field, and should not be construed as original laboratory or field research. All of the conclusions in this* Water Spectrum *article were contained either explicitly or implicitly in their earlier paper. Because of the diversity of disciplines among* Water Spectrum *readers, we have long felt that literature reviews in other scientific areas help to broaden our overall perspective of the field of water resources management.*

Introduction

The term "estuary" has been defined in a number of ways. Our definition, the one most commonly used by oceanographers, is that an estuary is a semi-enclosed coastal body of water which is freely connected to the open ocean and within which sea water is measurably diluted by freshwater from runoff. By adopting this definition as a starting point, we exclude from our consideration many important coastal environments: open coastal areas of low salinity such as the inner continental shelf off the U.S.; lagoons freely connected to the open sea but with little freshwater input; hypersaline lagoons such as Laguna Madre in which evaporation exceeds precipitation and runoff; and many marine wetlands.

Estuaries may be formed by a variety of geological processes: by building a barrier island partially across an embayment in the coastline, a bar-built estuary (e.g., Pamlico Sound), by large scale earth movements near the coast, a tectonically formed estuary (e.g., San Francisco Harbor); by drowning a glacially excavated trough, a fjord estuary (e.g., Russell Fjord, Alaska), or by drowning an old river valley by the rising sea, a submerged river valley estuary (e.g., Chesapeake Bay).

Dr. Schubel is director, and Mr. Hirschberg is a staff member, of the Marine Sciences Research Center, State University of New York at Stony Brook, 11794.

Trails of shrimp boats and plume from dredge in Corpus Christi Bay

Estuaries are common features of our coastlines today and have been for the past several thousand years. Because of their abundance; their high primary productivity; the large populations of commercially and recreationally important species of finfishes and shellfishes they support; and the varied uses man makes of them; a very important, sometimes even crucial, role in maintaining a well-balanced marine ecosystem has been attributed to estuaries. Like so many other natural features used by man, we take the existence and importance of estuaries almost for granted.

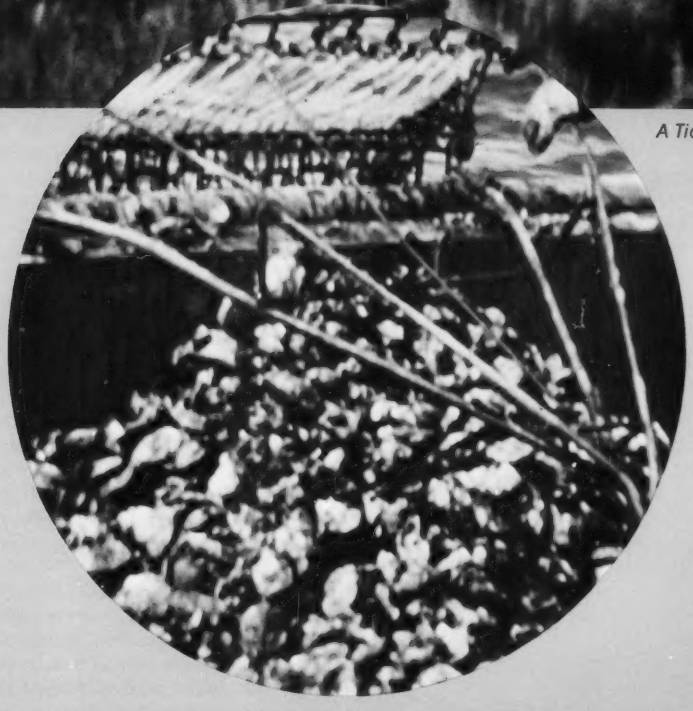
Each of us lives within a small piece of space-time; that part encompassed within the reach of our senses and the scope of our memories. This limitation yields a peculiarly parochial view of the world we use, almost without thinking, to define the "normal, usual, or average." "As it was in the beginning . . ." The broad expansive estuaries of today are perceived by many as permanent, natural features of our earth. They are there, they always have been and always will be. One of the services of science is to create an artificial "memory;" one that encompasses stretches of time far longer than those possible to individuals, or even to societies. We can begin to see the world as Nature sees it, on the geological time scale. From this vantage point our familiar "normal" world becomes a very strange place. Permanence becomes transience; the normal, the exception. Estuaries, viewed from this perspective, take on a different meaning.

The Birth, Life, and Death of an Estuary

The origin of estuaries is controlled primarily by those climatic events that determine world wide changes in sea level—glaciations and deglaciations. The distribution of estuaries is determined by the interplay of climatic events and regional and more local geological processes. Estuaries are relatively large and abundant after periods of rising sea level, particularly where continental margins are broad and relatively flat, such as along the Atlantic and Gulf coasts of the United States. Estuaries are smaller and less abundant during lowstands of sea level and where continental margins are narrow and the coast has high relief, such as along the Pacific coast of the United States.

All present-day estuaries are very young geologically. They were formed during the most recent rise in sea level which began a mere 12,000 to 15,000 years ago, and approached their present positions and configurations only within the past few thousand years. At the time of the most recent lowstand of sea level, the sea

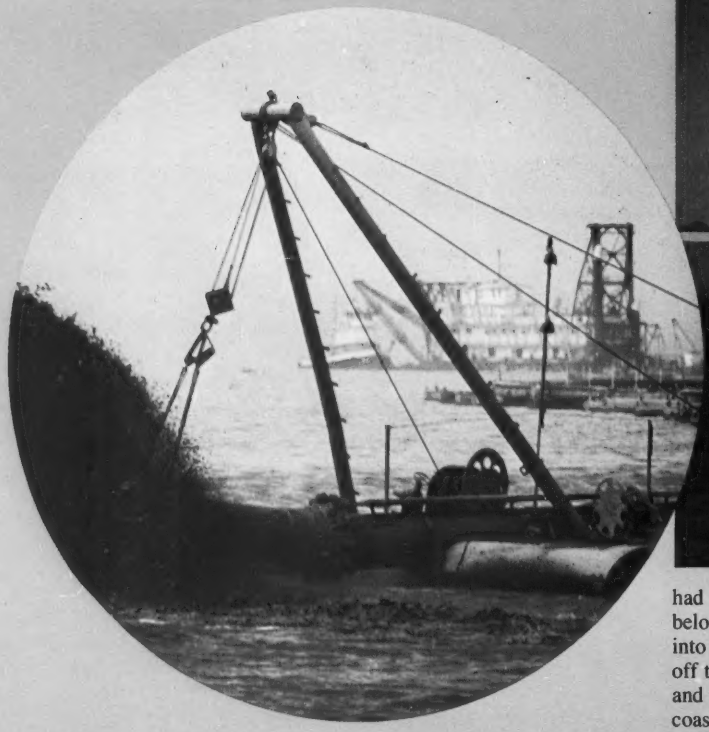
A Tidewater Virginia wetland. (Photos by the author unless otherwise noted.)



Oyster dredging on the Chesapeake Bay, Maryland.

Skipjack oyster dredges on the Chesapeake Bay.

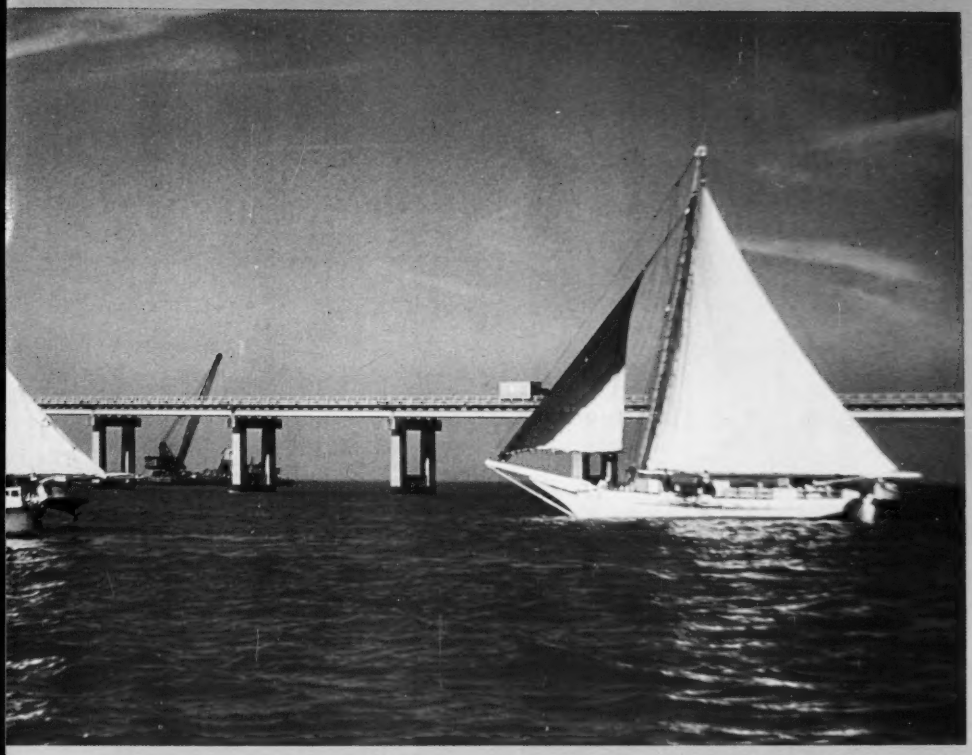
Dredging operations in the Atchafalaya Estuary



had fallen to a level approximately 100 meters below that of today. It had withdrawn entirely into its oceanic basin; the entire continental shelf off the east coast of the United States was high and dry and estuaries that existed off the east coast were confined to the heads of river valleys nicked into the shelf break.

When the glaciers began to retreat 12,000 to 15,000 years ago, the meltwater was returned to the sea and the sea began to rise. It climbed out of its oceanic basin and began its relentless march across the continental shelf. It continued to rise, and by about 10,000 years ago it had begun its invasion of the semi-enclosed coastal basins that dotted the coastline. It was this invasion that produced today's estuaries. Estuaries reached their peak in development—in number, size, and complexity—approximately 3000 to 5000 years ago when the rise of sea level slowed appreciably and the sea had reached nearly its present position.

Once formed, estuaries are rapidly destroyed. On a geological time scale they are ephemeral features having life spans measured in thousands of years to perhaps a few tens of thousands of years. They fill rapidly with sediments; sediments from rivers, from shore erosion, from biological activity, and from the sea. Characteristically, sedimentation rates are highest near the head of the estuary where a delta usually

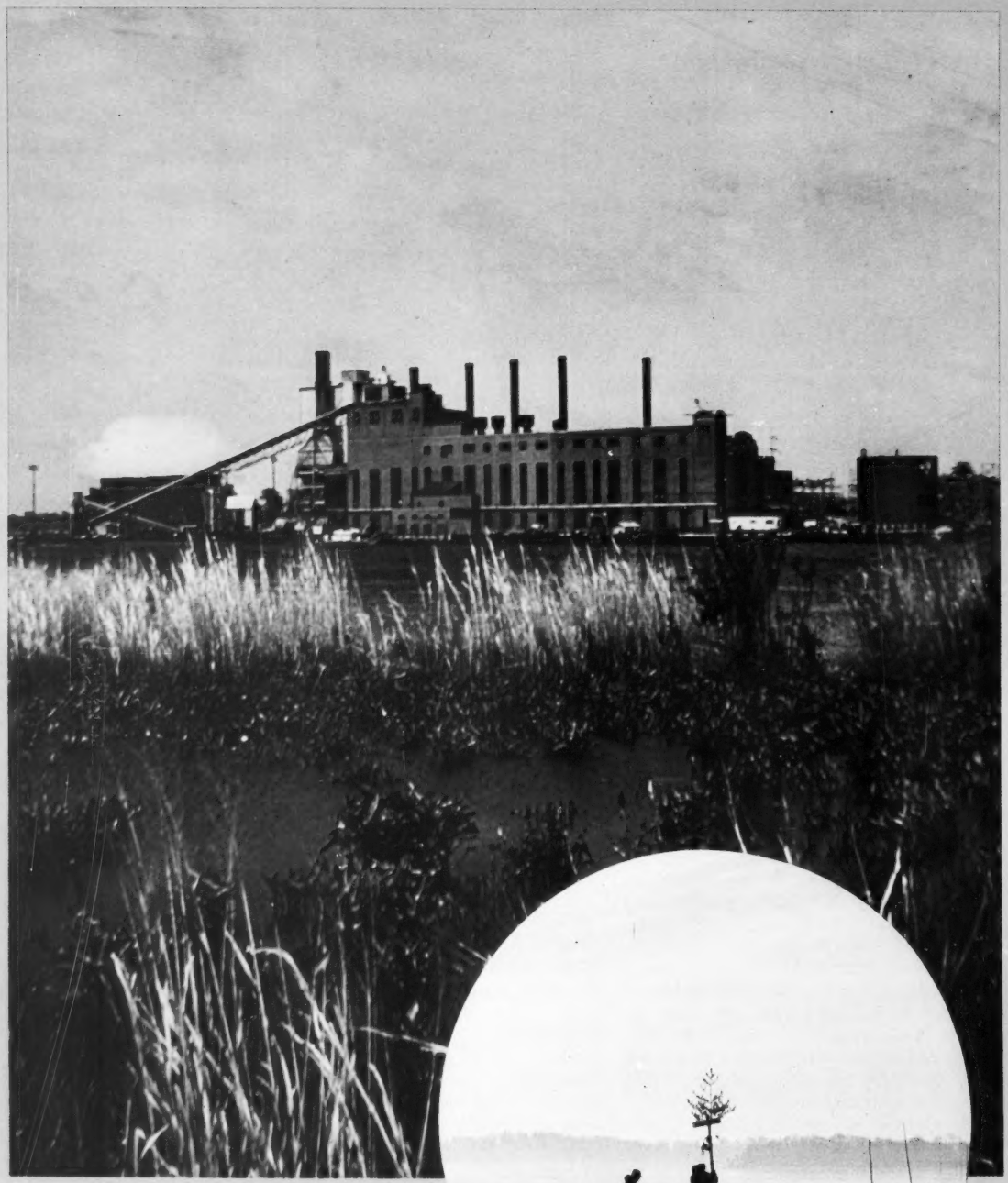


forms near the new river mouth. The delta grows progressively seaward within the estuary to extend the realm of the river and force the intruding sea out of the semi-enclosed coastal basin. In some estuaries, lateral accretion by marshes and deposition of marine sediments near their mouths may be important. Eventually, the intruding sea is displaced from the semi-enclosed coastal basin, the river reaches the sea through a broad depositional plain, and the transformation is complete. We can find estuaries around the world in various stages of development. It has been estimated that if all of the suspended sediment discharged by rivers, other than the Mississippi, into the lagoons and estuaries of the Atlantic and Gulf coasts of the United States were trapped within these coastal basins, they would be completely filled in 9500 years, assuming the sea remains at its present level.

The present time of high sea level, the Holocene Interglacial, has now lasted for more than 10,000 years, and represents a climatic regime that has been rare during at least the past one million years, and probably the past two to three million years, most of which have been occupied by colder glacial regimes. The most recent climatic analog to the warm, ice-free conditions of the present occurred about 125,000 years ago. The warmest part of that interglacial, the Eemian Interglacial lasted only about 10,000 years and was followed by an abrupt onset of a cold glacial period. Scientists believe that interglacial periods similar to the Holocene and Eemian have occurred on the average about every 100,000 years over the past one to three million years and that each has lasted about 10,000 years. The swings in sea level accompanying the advance and retreat of the glaciers have been about 100 meters.

Although estuaries were small and rare during the last, and previous lowstands of sea level. there were still extensive low salinity, open areas of the coastal ocean where today's estuarine-dependent organisms could, and apparently did, grow and reproduce. The proof of this is that these organisms survived the virtual absence of estuaries over about 90 percent of the past one to three million years. Their numbers were undoubtedly greatly reduced during glacial maxima—reduced to the point where fisheries for many of these organisms would have been difficult, if not impossible. But the species survived.

Today, glacial ice covers about 10 percent of the surface of the earth. About 90 percent of the total is concentrated in the huge Antarctic ice cap that is centered roughly on the South Pole. If this ice cap were to melt entirely—and it would take thousands of years to complete—the level of the oceans would increase worldwide by about 55



A power plant on Maryland's Nanticoke Estuary.

Striped bass fishermen on the Chesapeake Bay.

meters. A rapid rise of sea level, by human perceptions, could occur worldwide only by calving of large quantities of ice from Antarctica into the Southern Ocean. It has been estimated that a large surge of ice from Wilkes Land could raise sea level by as much as 17 meters in less than a century. Longer-term changes, changes over thousands of years, are almost certain to occur, and smaller, local changes in sea level are taking place because of adjustments in the earth's surface.

Our estuaries and adjacent coastal areas literally live under the Sword of Damocles. Even relatively minor swings in sea level would drastically affect our uses of estuaries. A drop of sea level of only 10 meters would completely drain more than 75 percent of the Chesapeake Bay estuarine system. Most of its oyster bars and clam beds would be high and dry; most of its shipping channels reduced to depths of 2 to 3 meters. A swing in the other direction would be no less disastrous. A 10 meter rise in sea level would inundate Baltimore, Washington, Norfolk, and the rest of the Chesapeake Bay's ports. Indeed, a 10 meter rise would drown most of the world's major coastal cities. The future trend of worldwide sea level changes is unclear, but change is the order of nature and any change is almost certain to be bad for man.

If sea level remains relatively constant, as it has for the past several thousand years, the life spans of most estuaries will depend upon sediment inputs controlled by the higher frequency climatic fluctuations associated with seasonal changes of annual period, and upon less frequent, but larger-scale weather events such as floods and hurricanes. Sediment inputs may be greatly affected by man's activities; they may be increased by clearing the land for agriculture and for urbanization, and they may be decreased by construction of reservoirs along the mainstems of major rivers. It has been estimated that the erosion rate in the drainage basin of the Susquehanna River increased 10 to 30 times at the peak of coal mining and agricultural activities in the 19th century.

Importance of Estuaries to the Marine Ecosystem and to Man

It is clear that many species of fin and shellfishes are dependent on low salinity waters for spawning and development during early life stages and that many of these species utilize estuaries for these functions. It has not been established unequivocally, however, even by those who argue most vocally, that these species are dependent on estuaries for survival. They must not be. If they were, they would have disappeared long ago. Modern (Holocene) estuaries have provided attractive sites for the concentration of a large number of species of fin and shellfishes, some of which are important to man. Estuaries offer relatively quiescent environments, protection from predators, and an abundant food supply. They are there. They are attractive sites and they are used. But they have not always been there and yet these so-called estuarine-dependent species have survived.

The importance of estuaries to the evolution of life has also been controversial. Opinions range from the view that estuaries are the last refuge of spent species, to the other extreme that life originated in estuaries. There is little evidence to support either of these views. There is no compelling evidence to indicate that estuaries have played an important evolutionary role for marine species. This is not surprising in view of the ephemeral character of individual estuaries and their low frequency of occurrence, at least during the last one to three million years, the Pleistocene. One might argue that estuaries may have played a more important role in the evolution of freshwater organisms since they provide the only continuous transition zone between marine and freshwater environments.

While existing data do not support the argument that estuaries are vital to the survival of estuarine-dependent finfishes and shellfishes, it is very likely that they are vital to the survival of the fisheries for these organisms. Without estuaries, the populations of many of these fishes would fall so low that viable fisheries could not be sustained. Fisheries are human activities which, for efficient and effective operation, require relatively large concentrations of organisms.

Estuaries are of the greatest importance; not to the survival of species, or to the maintenance of the entire marine ecosystem, but to man. Of all the organisms which use estuaries, man makes the most varied demands on them. Man is clearly the most estuarine-dependent organism in the biosphere. The estuarine zone is approximately twice as densely populated as the rest of the Nation. Man uses estuaries for activities which

Clams harvested from the Chesapeake Bay.

may be, and indeed frequently are, in conflict. He uses them for their extractable resources, both organic and inorganic; for shipping and transportation; for military activities; as a transient receiver for his human and industrial wastes; as a source of cooling water for power plants; and he uses them for recreation and re-creation.

Wise management of the coastal environment may have little effect on the span of time an estuary occupies in the geological record. That will be determined primarily by climatic events, although poor soil conservation practices throughout an estuary's drainage basin may increase the sediment yield and the rate of infilling of the estuary and shorten its lifetime by a factor of two or more. There are more serious consequences of the absence of sound estuarine management. Without effective management the biologically and recreationally useful life of an estuary can easily fall short of its geological life by an order of magnitude. Such negligent shortening of the useful life of an estuary may not spell disaster for the survival of estuarine-dependent shellfish and finfish, but for estuarine-dependent man it surely would be a serious loss. Of all the organisms which use estuaries, man is the only rational one among them. He is the only one capable of managing them; he is their custodian. It's up to us.

Conclusions

☐ Estuaries are semi-enclosed coastal bodies of water freely connected to the ocean within which seawater is mixed with and measureably diluted by freshwater from land runoff.

☐ All modern day estuaries are very young geologically.

☐ The occurrence and distribution of estuaries is controlled by climatic changes associated with alternating glacial and interglacial periods and the resulting worldwide swings of sea level.

☐ Estuaries are large and abundant during highstands of sea level, small and rare during lowstands.

☐ Interglacials similar to the present Holocene Interglacial have occurred about every 100,000 years during the last 1-3 million years, and have been shortlived.

☐ Estuaries have not been persistent geomorphological features throughout geological time; low salinity, open coastal areas have been.

☐ During glacial periods when sea level was low and estuaries were rare or absent, estuarine-dependent organisms must have lived and reproduced in open, shallow, brackish areas.

☐ Estuaries are not vital to the survival of *species*.

☐ Estuaries have not played an important role in the evolution of marine species.

☐ Estuaries are attractive sites for the concentration of large numbers of relatively small numbers of species, some of which are important to man.

☐ Estuarine-dependent finfishes and shellfishes would not disappear if estuaries were eliminated by a drop in sea level or if they were seriously polluted and degraded by man; estuarine *fisheries* might well disappear.

☐ Man is the most estuarine-dependent organism in the biosphere. He makes the most demands on the estuary—often conflicting—and is the only organism with the rationality to manage it.

☐ Rational management of the coastal environment may have little effect on the time an estuary occupies in the geological record, but without effective management an estuary's biologically and recreationally useful lifetime can easily fall short of its geological lifetime. This would be a tragic loss for estuarine-dependent man. ■

Waterfowl along New York's Great South Bay.

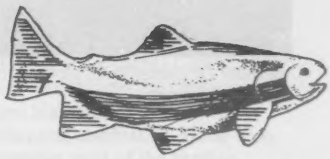
Improving Stream Fisheries

by O. Eugene Maughan and Kent L. Nelson

A log dam in place along North Creek, Jefferson National Forest, (Botetourt County), Virginia.

(Photos by Kent L. Nelson)

The condition of a stream ecosystem is intimately related to the state of the surrounding watershed; with its productivity generally determined by the productivity of the land it drains. We are, however, less attuned to the realization that any adverse land use practices in the drainage area can have detrimental impacts on the stream. Most often the result of adverse land use is increased sedimentation. Sedimentation in turn can reduce the numbers of aquatic organisms which are important as fish food and can kill fish eggs.



In attempts to ameliorate adverse impacts or enhance natural conditions, stream improvement practices have been widely used. These practices range from land treatments such as fencing stream banks from livestock and protecting eroding areas with rock revetment, to the installation of instream structures such as deflectors and dams.

The effects of improvement devices on stream fish populations have varied. Usually, significant positive effects result only when improvements remedy a factor or factors that are limiting the expansion of fish populations. As an example, *Hunt* (1971)[1], in studies conducted on Lawrence Creek, Wisconsin, found that the amount of pool area and permanent cover limited trout abundance. After Hunt installed a series of bank covers and current deflectors to increase the amount of pools and cover, the trout biomass and harvest more than doubled. His efforts would, of course, have been wasted if seasonal intermittence or reduced dissolved oxygen levels rather than the scarcity of pools and cover had been the factors limiting fish production. Limiting factors may or may not

Dr. Maughan is with the Fish and Wildlife Service, Oklahoma State University, Stillwater 74074. Mr. Nelson is employed by the North Carolina Wildlife Resources Commission, Fayetteville 28304.

[1]*Hunt, R. L., 1971. Responses of a brook trout population to habitat development in Lawrence Creek, Wisc. Dept. of Nat. Resources Tech. Bull., 48.*

Boulder emplacements along Crooked Creek in Carroll County, Virginia.

be readily identifiable, and in some streams corrective action would be futile or prohibitively expensive. A stream that is being degraded by poor land use practices benefits little from instream structures unless conditions in the watershed are also improved. Therefore, before stream improvement work is undertaken, factors such as physical and chemical stream and watershed characteristics, flow regime and bank stability must be analyzed.

The effectiveness of various structures is also dependent on proper placement and procedures, as well as on watershed characteristics. Procedures that are functional in certain areas have proved unsatisfactory in others. For example, the removal of the stream canopy recommended for northern trout streams, to promote the production of plankton and aquatic macrophytes, would be detrimental on southeastern trout streams, where removal might result in critically high summer water temperatures. The improper use or design of habitat improvement structures can be more detrimental than no action, if the structures result in bank erosion, increased flooding potential, or formation of migrational blocks.

State and Federal programs designed to increase the abundance of stream fishes through habitat management were initiated in the 1930s. The Civilian Conservation Corps provided the labor for construction, but thorough pre- and post-project evaluations were seldom conducted. Most of the early work was concentrated on trout streams. Limited analysis of results showed highly variable responses. Improper design and construction and incorrect identification of limiting factors were the primary causes of failure of many of these structures to improve stream conditions. Log dams were often washed out or undercut, or the stream banks were eroded as a result of the dam presenting too high a profile or being improperly reinforced. In some streams erosion problems were created by the placement of structures in unsuitable locations or in proximity to unstable banks.

Results were successful, however, when structures were designed within the limitations dictated by the physical characteristics of the individual stream and the limiting factors of the fish population concerned. For example, *Shetter, Clark and Hazzard* (1946)[2] found that log deflectors placed in a Michigan trout stream that had a sand and gravel base increased depth and number of pools, trout standing crop, and angler success. An increase in trout food species was also noted.

The importance of cover to the fish has been evaluated in some recent studies on stream alteration. It has been noted that the territory occupied by trout is often oriented in relation to stream cover such as large rocks, turbulent surface waters and submerged logs. Shaded areas form preferred habitat in water that typically has high light transmittance. Hiding cover is also important in reducing predation and competition. An example of data of this type is presented by *Saunders and Smith* (1962)[3] who found

[2]*Shetter, D. S., O. H. Clark and A. S. Hazzard. 1946. The effects of deflectors in a section of a Michigan trout stream. Trans. Amer. Fish. Soc. 76: 248-278.*

[3]*Saunders, J. W. and M. W. Smith, 1962. Physical alteration of stream habitat to improve brook trout production. Trans. Amer. Fish. Soc. 91 (2): 185-188*

higher survival rates of brook trout in a Canadian stream after the emplacement of log dams, deflectors, and wired alder and spruce cover devices.

There has been little study of the effects of habitat improvement on warm-water streams. However, several attempts have been made to offset the detrimental impact of channelization by the installation of stream improvement structures. In general, channelization reduces habitat variability, water depth, and velocity and reduces the total amount of habitat by reducing stream length. The loss of environmental variety results in the loss of organisms whose requirements are not met by the restricted conditions. Habitat improvements in channelized streams are usually designed to increase habitat diversity through formation of pools and cover. Such a procedure can simulate prechannelization conditions. For example, the installation of deflectors and check dams in a channelized section of the Weber River, Utah, resulted in the restructuring of the channel to resemble the riffles and pools of an unaltered stream *(Barton and Winger, 1973)*.[4]

Stream improvement structures are currently widely used in the southeastern U.S. to offset the effects of habitat changes generally resulting from changes of land use in the watershed. Recently we have been involved in a study of these procedures, particularly in Virginia trout streams, which was funded by the Virginia Water Resources Research Center (*Maughan, Nelson and Ney,* 1978)[5]. The structures on the four study streams consisted of log dams, rock-filled gabions (rectangular wire cribs of various dimensions) and boulder emplacements. Log dams and gabions are intended to restructure streams to provide additional deep water habitat, and boulder emplacements are designed to increase instream cover and hiding space. Pools are formed below dams through the scouring of substrate materials, and often above the dams from the impounding of the stream. Gabions deflect the current into a restricted channel and, through an increase in velocity, scour a deeper channel. Gabions are used singly or in pairs and also can function to remove silt from stream channels, close alternative channels, and protect eroding banks. The use of log dams is restricted to streams with a maximum discharge below 100 cubic feet per second (cfs). At higher stream flows log structures are washed out and destroyed. On streams subjected to occasional flooding, dams must present a low profile, have their ends well embedded in the banks, and be reinforced with rock.

To evaluate the effectiveness of various structures, we compared stream physical characteristics, aquatic macroinvertebrates and fish populations in improved and unimproved sections of four Virginia streams.

Fish were collected with a 230-volt DC electro-shocker from 50 meter sample stations. Block seines at the station boundaries precluded the movement of fish into or out of the area during sampling. Benthic invertebrate populations were collected using a circular substrate sampler. The physical characteristics examined included stream width, depth, current velocity, substrate composition and riffle-pool ratio.

The study streams were North and Jenning Creeks (Jefferson National Forest, Botetourt Co.), Comers Creek (Mt. Rogers National Recreation Area, Smyth Co.) and Crooked Creek (Carroll Co.). The streams are typical of southeastern trout waters, which flow along mountain slopes and are characterized by steep gradients, rapid runoff and periodic flooding. Three of the streams, Crooked Creek excepted, flow through forested land, are well shaded, and have substrates composed primarily of stone and gravel. Oak, hickory, and yellow poplar dominate the forest community, and rhododendron and mountain laurel are abundant in the understory. In contrast, the Crooked Creek watershed supports extensive livestock grazing, and adverse agricultural practices contribute substantial amounts of sediment to the stream. Streamside vegetation along Crooked Creek is primarily multiflora rose, creek willow and sycamore.

The fish community of the streams is dominated by the minnow family *(Cyprinidae)*, the most common representatives being the stoneroller, mountain redbelly dace and blacknose dace. Other abundant fishes are the mottled and slimy sculpin, torrent sucker and the northern hog sucker. The number of species of fish present ranged from five on Comers Creek to 15 on Jennings Creek. The aquatic insects found in the study streams are characteristic of cold, well-oxygenated and high-quality waters. Many species of mayflies, stoneflies and caddisflies, along with the true flies *(Diptera)*, comprise most of the benthic fauna.

A gabion deflector on Jennings Creek, Jefferson National Forest, Virginia.

[4] *Barton, J. R. and P. V. Winger. 1973. A study of the channelization of the Weber River, Summit County, Utah. Utah Division of Wild. Resour. and Utah State Dept. of Highways.*

[5] *Maughan, O. E., K. L. Nelson and J. J. Ney. 1978. Evaluation of stream improvement practices in southeastern trout streams. Va. Water Resour. Research Cent. Bull. 115.*

On North Creek, pool area in the improved section was approximately seven percent higher in the improved section than in unimproved sections. The greatest area of pool formation occurred above the dams, with smaller pools scoured below each dam. Since the dams on North Creek had been in place more than 35 years, the upstream pools were apparently stable. An increase in pool area was also noted within the structure-improved sections of Comers Creek. However, two dams were washed out in April 1977 when discharge reached approximately 240 cfs. The improper placement of the dams immediately downstream from a meander was probably the primary factor involved in their destruction. The use by trout and other fish species of the pools found in association with the log dams was greatest during summer low flow periods, when other stream sections began to dry. Increasing fishing pressure in the large conspicuous pools was also observed.

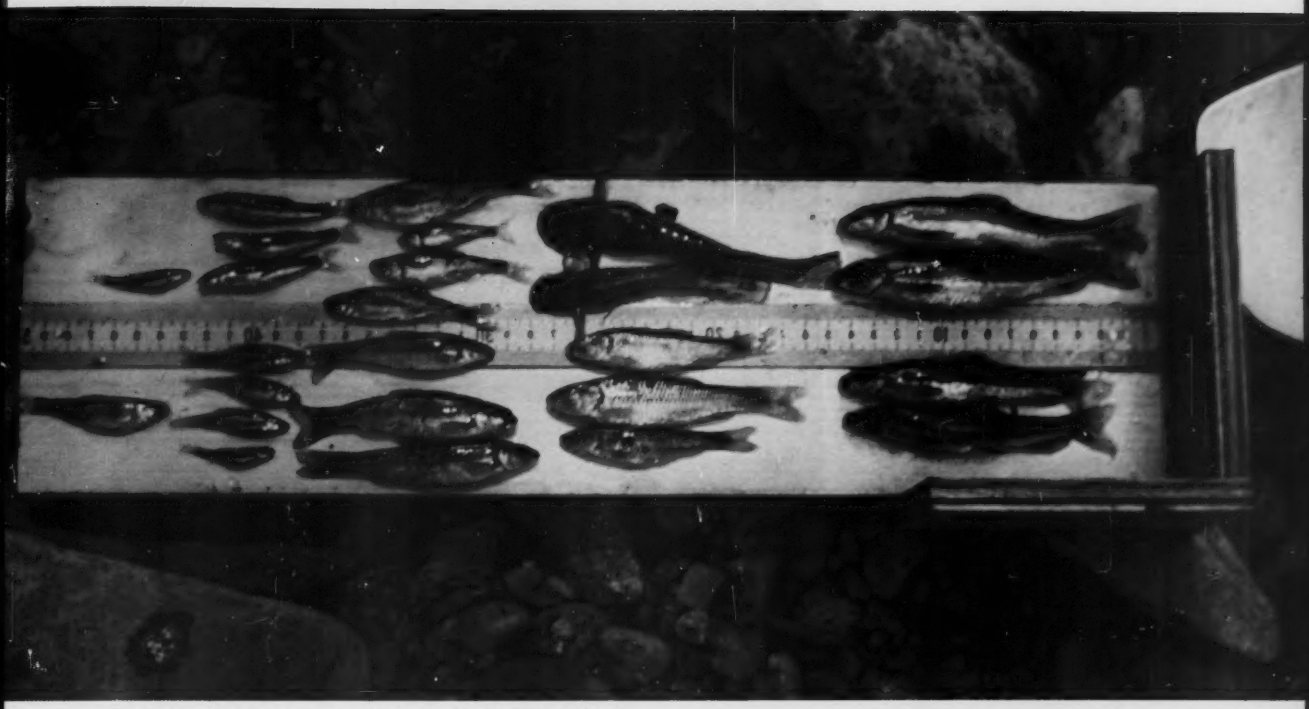
In North Creek the total biomass of fish cumulated over the study period was greater within the sections containing the log dams than in unaltered areas. During four of the six fish samples taken on the two streams containing log dams, total weight of trout was greatest in the sections in which the habitat had been improved. However, the dams may not have functioned optimally because the pools formed by the structures were generally devoid of cover, except for areas of turbulent water below the dams and the rock used to reinforce the ends of the structures. No significant differences were found in macroinvertebrate populations between improved and unimproved areas, but slight increases of sand and fine particulate matter were noted in the quiet waters associated with the impounded pools.

A log dam on Comers Creek in the Mt. Rogers National Recreation Area (Smyth County), Virginia.

Nine single and nine paired gabions were present on Jennings Creek, but the evaluation of the physical effects of the gabions was confounded by the lack of data from before emplacement. Although pools were in close proximity to 11 of 18 gabions, it is not known whether the pools existed prior to or subsequent to the construction. The authors surmise that in the areas where pools began above the gabions, the structures were placed there to enhance and maintain the existing pools. Pools that start at the beginning of the paired gabions likely reflect pool formation subsequent to gabion placement. A number of the single gabions were placed on the outside bend of meanders to direct the stream away from the nearby roadbed. The pools near the paired gabions were sgenerally restricted to a width equal to the diameter of the opening between the gabions. The water behind both single and paired gabions was generally shallow (less than 30 cm) and deposition of sand, silt and detritus was common in this quiet water. No significant differences were found between the study sections in total fish or trout biomass or benthic invertebrate populations over three sampling periods. The general absence of cover associated with the gabions may explain the lack of effect.

The objective of single and multiple boulder placements in Crooked Creek was the development of additional cover through undercutting and pool formation. Five of the 12 placements did result in undercutting and significant depth increases. (Depth, itself, creates cover.) The boulders created some turbulence and tended to accumulate debris, both of which provided additional cover for trout. The depth before placement greatly influenced the effectiveness of the boulders. When the boulders were in the deeper portions of the channel, the current undercut the sides and occasionally the upstream face of the rocks. Conversely, little undercutting occurred when the boulders were placed in the shallower sections of the stream.

The high sand content in Crooked Creek resulted in extensive deposition in the areas of reduced current velocity behind the boulders. Deposition was reduced or eliminated when the boulders were situated close together. The deflection of the current by the boulders during periods of high streamflow presented a problem, in that erosion and damage was noticeable in some areas where large boulders were placed close to the banks. Although no statistically significant differences in total fish or trout biomass were found between the sections containing boulders and unimproved areas, the use of the boulders by trout was apparent during electro-shocking. Significant differences were likewise not found between the aquatic invertebrate populations or physical characteristics of the



Representative fish taken during a sampling on North Creek (Botetourt County), Virginia.

stream in the study sections. In summary, while an increase in pool area resulted from the installation of log dams and gabions, no statistically significant differences were found in the fish biomass or benthic invertebrate numbers or kinds among habitat improved areas and unimproved sections of the four streams. However, total fish and trout biomass was more often higher in association with the log dam sections than either gabion or boulder emplacements. As the pools forms by the log dams and gabions were generally lacking in cover, the structures may not be functioning optimally. The increase in fishing pressure observed near the structures further complicates analysis.

The log dams and gabions studied were found to be susceptible to destruction by high flows; however, proper construction design and a low profile could have prolonged their lifespan. The primary study objective of these dams and gabions was to increase pool area, therefore, only in streams where the lack of pools is considered the limiting factor, should their use be considered. Analysis of the depth profiles on unaltered sections of North and Comers Creeks showed only a very low percentage of deepwater habitat (less than three percent). Therefore, these streams would seem to be reasonable candidates for this type of structure. Boulder emplacements, when situated in deeper sections of the channel, caused undercutting and provided cover for fish. Boulders are therefore applicable in situations where cover is considered to be limiting. When boulders were placed in shallow areas, little undercutting occurred. Boulders can be used in larger streams than those suitable for gabions or dams, and are natural in appearance and can be assumed to function indefinitely. However, the use of boulders may be impractical when they are not available in proximity to the stream. ■

Corrections are made on a negative for a 1:100,000 scale wetland map.

In Search of Wetlands

by Rudolf Nyc

Next time you go fishing in a cypress swamp, don't think of it as home for bass, but rather as a Palustrine, forested, needle-leaved, deciduous wetland with a permanent water regime. Such adjustments in concept will be necessary to use the U.S. Fish and Wildlife Service's National Wetlands Inventory products. Centuries old colloquial terms for wetlands—such as bogs, swamps, marshes, and fens—are not recognized by the new system.

The need for a new wetland inventory is due principally to a better understanding of wetland ecology and changes, both natural and man-induced, which have occurred since the first national wetlands inventory was completed in 1954. Also, subsequent to the completion of the first wetland inventory, Federal[1] and state legislation[2] directed at protecting wetlands has been enacted, causing a proliferation of regional and statewide wetland inventories utilizing a variety of classification systems—none of which could be applied nationwide.

In 1974, the Fish and Wildlife Service (FWS) established the National Wetlands Inventory (NWI) with the stated objective of inventorying and mapping all wetlands and developing a classification system that groups ecologically similar wetland habitats, so that value judgments could be made and uniformity in concepts and terminology throughout the United States be provided.

The previous wetland inventory utilized a classification system that compartmentalized wetlands into 20 broad types (*Circular 39*, Martin *et al.*, 1953). This was satisfactory at the time since the purpose of this inventory was principally to assess waterfowl habitat. The old classification system, however, could not be used to effectively achieve the broader goals of the new NWI. Numerous other classification systems were reviewed but could not be used by the NWI because of their regional orientation and use of colloquial terms, such as bogs and swamps, which have different meanings in different parts of the country. The decision was then made to develop a new national wetland classification system.

Concurrently, while evaluating existing systems and developing its new classification system, the NWI staff was communicating with potential users of its products, including the Corps of Engineers, to ascertain the desired degree of detail, scale of maps, and types of records that would best satisfy their needs. Although the NWI found that the needs of the user community were varied, it became evident that there was an overwhelming need for detailed wetland information pertaining to location, classification, size and functional value of wetlands.

After evaluating various methods to perform the inventory, including LANDSAT, large and small scale aerial photography, and a combination of map interpretation in conjunction with extensive field work, the NWI group concluded that the most cost-effective procedure to achieve the desired level of detail and accuracy was to use stereoscopic interpretation of high quality, small scale, aerial photography.

Mr. Nyc serves as the U.S. Army Corps of Engineers' representative on the multi-agency National Wetlands Inventory.

[1]Clean Water Act of 1977, as amended.

[2]Most states are involved in some type of regulatory or nonregulatory wetland "protection" program, but the scope of these programs varies. "Strengthening State Wetland Regulations," prepared for the NWI by Jon A. Kusler of the Environmental Law Institute provides an overview and comparison of state wetland programs.

By the time the decision on how to perform the inventory was made, the new classification system had undergone three major revisions as a result of years of extensive scientific and technical review. This document was then published as an "operational draft" in October 1977 *(Classification of Wetlands and Deep-Water Habitats of the United States,* Cowardin *et al.)* and became the cornerstone of the new NWI.

The new classification system consists of five broad ecological systems, each of which contains a hierarchical structure that describes, in progressively greater detail, hydrological, biological, and physical components of a wetland or water body. To achieve an even greater degree of descriptive detail, modifiers for water regime, water chemistry, soils, and a man-influenced category which contains items such as "diked/impounded" are added to the information provided by the hierarchical portion of the classification system. Although the system appears to be formidable when first encountered, with some training it is relatively easy to master and simpler to use for inventorying large areas than other existing classification systems.

National Wetlands Inventory staffers studying wetland plant community associations and soil composition.

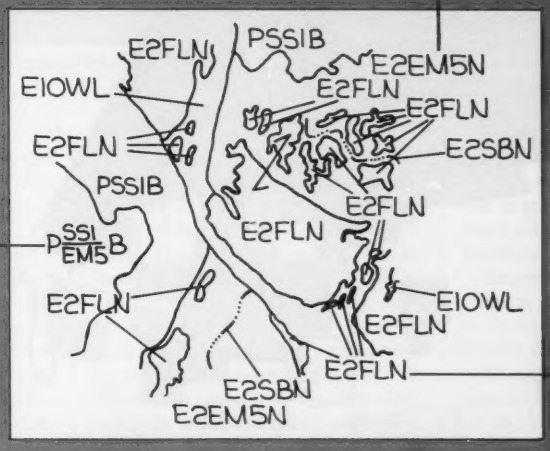
Each element of the classification system is identified by either a letter or a number. The composite code identifying a particular wetland, consisting of a series of letters and numbers, is known as an alpha-numeric. To ensure national consistency, mapping conventions have been developed and are being strictly adhered to.

As an expression of support and in recognition of the potential impact this project could have, the U.S. Geological Survey, Soil Conservation Service, and Corps of Engineers assigned full-time representatives to the NWI central office in St. Petersburg, Florida. Those Federal agencies involved with wetlands, but unable to assign full-time representatives, have established points of contact to ensure coordination with the NWI.

Interagency (Federal, state, and local) involvement and cooperation is a major factor for the successful completion of the wetlands inventory. This cooperation is fostered by maintaining an NWI staff in Washington, DC, and at each of the regional Fish and Wildlife Service offices plus Alaska, in addition to the central office in St. Petersburg. The regional wetland coordinators are also responsible for monitoring contracts, performing field checks, and verifying accuracy of maps and overlays within their respective regions.

By the end of 1979, the NWI had inventoried 153,600,000 acres of the U.S., producing 3,325 large scale (1:24,000 or 1:62,500 depending on availability of base maps), and 133-1:100,000 scale maps.

E2EM5N—
Estuarine intertidal emergent consisting of *Carex lyngbyei* (Lyngbyei's sedge).



(Portion of Overlay for 1:62,500 USGS MAP)

PSS1/EM5B—
A mixture of scrub/shrub and emergent vegetation consisting predominantly of *Betula nana* (Dwarf birch), *Andromeda polifolia* (Sprouting willow), *Ledum decumbens* (Labrador tea), *Calamagrostis canadensis* (Bluejoint), and *Carex bigelowi* (Bigelow sedge).

Representative Wetland Types

E2FLN—
An estuarine flat which, though not vegetated, is still considered to be a wetland. These flats produce abundant benthic (bottom) organisms that are an important food supply for wading birds and aquatic animals.

LEGEND
NWI draft of final overlays completed by January 1980.
NWI in progress—fully or partially funded.*
Depending on funding, priority areas planned for completion by January 1982.*
*Subject to change.

A wetlands soil sample is checked against the Munsell color book and taxonomy guide to determine hydric content.

The NWI has a limited reproduction and dissemination capability that was implemented in order to make maps and overlays available to potential users. To date, 25,000 copies of draft and final overlays have been distributed under this interim dissemination program. The long-term dissemination strategy is to utilize, through a cooperative agreement, the U.S. Geological Survey's reproduction and distribution facilities for dissemination of NWI products. For information concerning the availability of NWI products, contact the appropriate Regional Wetland Coordinator.

In addition to the wetland information, the small scale maps contain Bailey's Ecoregion, Hammond's Landform, and U.S. Geological Survey hydrologic unit boundaries. For each large and small scale map there will be a computer printout that will aggregate wetland information by the number of acres of a particular wetland type within a county, state, ecoregion, landform, and hydrologic unit. This should prove very useful in preparing Environmental Assessments and Environmental Impact Statements.

When using these maps and overlays, it is important to remember that the NWI is inventorying *all* wetlands without emphasis on any particular type—such as in the first national wetlands inventory—and not restricting the mapping to only those wetlands regulated by Federal, state, or local regulatory agencies. Also, since the wetland definition in the new classification system involves consideration of several parameters: vegetation, animals, soils and hydrology, it may appear broader in concept than a definition based on fewer parameters. For example, if a definition is based principally on vegetation, then technically, an unvegetated mud flat would not be considered a wetland.

Perhaps the most controversial part of the wetland concept employed by the NWI is the inclusion of the transitional zone—that fuzzy boundary where wetland and upland plants share common ground—in the wetland category. Arguing whether the transitional zone is a wet upland or a dry wetland will serve little purpose at this time since our knowledge of the ecological and functional attributes of these unique ecotones is very limited.

What is important is that the transitional zone can be identified by the water regime modifiers on NWI maps/overlays. Transitional zone studies being conducted jointly by the Corps of Engineers' Waterways Experiment Station and the U.S. Environmental Protection Agency are expected to result in guidance and methodologies for more accurately delineating the landward boundary of regulatory wetlands.

Because of possible technical differences in concept and the requirement to consider the additional statutory criteria for determinations of jurisdiction, wetlands regulated by Federal, state and local agencies may be a subset of the wetlands depicted on NWI maps/overlays. A special note is contained on all NWI products, stating that there was no attempt to define the limits of proprietary jurisdiction of regulatory agencies and alerting the user to seek the advice of appropriate Federal, state or local agencies concerning possible regulatory jurisdiction if any work is contemplated within or adjacent to a wetland area depicted on the NWI map or overlay. Section 404 of the Clean Water Act of 1977 (CWA of 77), as amended, identifies the categories of wetlands subject to the federal regulatory program and provides a mechanism for transferring regulatory responsibility for certain of these wetland categories to states that comply with pertinent regulations. By knowing where all the wetlands are located, it should be easier to identify those wetland categories addressed in the CWA

of 77. If this could be accomplished, it would assist in providing a means for an orderly transfer of regulatory responsibility to states that have obtained the necessary approval. It could also differentiate where permits from state or Federal agencies would be required and may also prove useful for monitoring state compliance with Federal transfer regulations. This may be wishful thinking for it may not be easily attainable due to technical and legal problems, but is certainly worth an attempt.

Some Corps of Engineers Districts are experimenting with depicting regulatory wetlands on NWI maps/ overlays.

Wetlands are living systems and, as such, do change in response to changing environmental conditions. Rapid alteration, destruction or creation of wetlands is principally associated with acts of major catastrophic events. Natural change in wetlands is slower and more subtle and occurs over a relatively long period of time in a generally predictable manner. If the water regime of a wetland is significantly altered, a change in the wetland can be expected in time. The most rapid natural change would most likely be in response to seasonal and climatic conditions and would manifest itself in the species of plants and animals that are present, while the slowest change would be the origin or demise of a wetland. There are, of course, exceptions to this, such as wetlands created by beaver dams and meandering streams.

The point is that unless affected by man or a catastrophic event, a particular wetland will persist for a very long time.

One unconfirmed, educated guess is that from 1970 to 1980 an average of about 5% of the wetlands on a set of maps will have undergone radical change.

Scale, image quality, type, season and year of high altitude aerial photographs used, proficiency of the photointerpreters and cartographic (map producing) team and portion of the country being inventoried are all important factors that determine the accuracy and detail of NWI maps and overlays. Even with the recently implemented, stringent, quality control procedures at each step of the inventory, accuracy and detail of NWI products continues to vary due to these variables.

A portion of a color infra-red aerial photograph taken along Cook Inlet, Alaska. Annotated portion is representative of wetland classification.

Field review (by Corps of Engineers' personnel) in diverse parts of the country, including Oregon, Georgia, Florida, Vermont, New Jersey, Maine, and Arizona, have shown that the NWI maps are surprisingly accurate and detailed, particularly in view of the potential for error inherent in the procedure used to perform the inventory. Because of the potential for errors by any resource mapping effort, NWI maps/ overlays should not be used to eliminate field review. However, once the accuracy of the wetland map has been confirmed or the data refined, subsequent field trips may be minimized.

The official NWI minimum mapping unit (the smallest wetland mapped) is between one and five acres, depending on scale and type of aerial photographs. In reality, this varies. In South Florida, wetlands three acres and larger were mapped consistently using 1:80,000 color infrared photography. According to the photointerpreter who performed the task, it was the sheer density of wetlands that precluded mapping smaller units consistently, although wetlands of about ⅓ acre were mapped where the density of wetlands was less. In the Prairie Pothole region (Min-

nesota, North Dakota, and South Dakota), the NWI has demonstrated that with 1:60,000 color infrared photography it can map units as small as 1/10 acre consistently and down to 1/40 acre on occasion. Conversely, some wetlands larger than five acres have been missed. A very high percentage of the larger wetlands missed are of the dryer type that do not contain discernible tonal differences from upland areas on the aerial photographs. Frequently, such areas are transitional in nature, exhibiting both wet and dry characteristics.

In order to comply fully with its mandate, the NWI is also involved in developing a technical data base and preparing a variety of reports concerning wetlands.

The Soil Conservation Service representative assigned to the NWI is compiling a list of hydric soils for the entire nation, including Alaska and Hawaii. A preliminary list for selected portions of the country will be available during spring 1980. In addition to helping identify wetlands in the field, this list will make existing products, such as the Soil Conservation Service's soil survey maps, more useful as a data base for wetland evaluation.

The FWS staff at the NWI is developing a comprehensive wetland plant data base that will be used to more precisely define and identify wetlands. This data base should be available in draft form during 1981, although a preliminary list of wetland plant species with some additional information such as where these plants occur, their wetland specificity or indicator status, and flowering time of the species, will be available during 1980.

The previous national wetlands inventory estimated that 45 million acres of wetlands had been destroyed since 1950. In order to document changes that have occurred in wetlands since this last national wetlands inventory, the NWI is conducting a trend analysis that will utilize 1950 and 1970 era aerial photographs, the new wetland classification system, and sophisticated statistical procedures. This effort is expected to be completed by December 1981.

An NWI overlay is checked against field conditions during permit review

For all areas inventoried, the NWI will prepare reports that will document the status of the wetlands for that area. Ultimately, all NWI products will be consolidated and summarized in an

Potential Uses of NWI Wetland Maps and Overlays

Small Scale Maps (1:100,000)

- Basin-wide planning
- General overview of wetland information
- Display of additional information pertinent to wetlands such as
  - —Alternate project sites
  - —Navigable waters of the U.S.
  - —Section 404 wetlands
  - —Wetlands covered by nation-wide permits
  - —Wetlands covered by general permits
  - —Critical habitat

Large Scale Overlays (1:24,000 to 1:62,500)

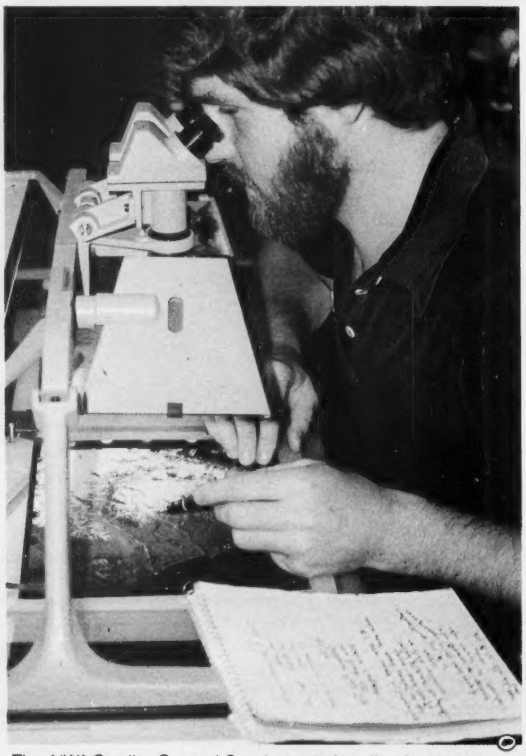
- To facilitate field review and setting of priorities for inspection
- To assist in design and project alternatives that avoid or minimize impact on wetlands, transitional zones, and open water
- To communicate by referencing NWI codes, coordinates, and name of map
- As data base with file referencing NWI code, coordinates, and name of map with information concerning field visit and rationale for determination of jurisdiction, information on vegetation, etc.
- To depict jurisdiction, on a case by case basis, following field review.
- To show where nation-wide permits have been issued and for issuing general permits
- For mitigation with similar wetland types
- For habitat characterization
- For periodic reinventorying to determine cumulative impacts and trends
- To assess general or range of values for wetlands (functional curves)

authoritative report on the nation's wetlands.

The NWI has developed a Wetland Analytical Mapping System (WAMS), which, when fully operational, will make it possible to digitize wetland information directly from aerial photographs to produce wetland maps that are more accurate than those made from the current cartographic procedures. WAMS will also make it possible to rapidly update site-specific information and retrieve data either as a computer printout or as a map at any desired scale. WAMS is currently undergoing pre-operational testing at Fort Collins, Colorado.

During 1979, in a cooperative effort aimed at achieving greater efficiency in acquiring aerial photography, 12 agencies pooled their resources and formed the Federal High Altitude Aerial Photography Data Base Programs. After lengthy discussions, it was decided that 1:80,000 black and white and 1:60,000 color infrared aerial photography, imaged simultaneously, would best satisfy the needs of this diverse interagency group. Approximately 300,000 square miles of the country have been selected by this group for air photo acquisition during 1980, the first year of its operation. During a three- to five-year cycle, this program will obtain imagery over the entire United States, with the exception of Hawaii and Alaska. Because of its expertise in this field, the U.S. Geological Survey is the lead agency for this program and it will ensure that the quality of aerial photography obtained complies with its stringent specifications. This program will be the principal source of high altitude aerial photography for the NWI.

According to Paul Brooks, the U.S. Geological Survey Representative assigned to the NWI, "With the high quality imagery of the desired scale and type virtually assured by the new Federal High Altitude Aerial Photography Data Base and the promising results from the pre-operational testing of the Wetlands Analytical Mapping System, we should be able to produce more maps and overlays faster and of better quality than previously." Indications are that the relative cost of mapping wetlands will also decrease in the future.



The NWI Quality Control Section continually checks the accuracy of photointerpretation, using high power stereoscopes.

The need for a comprehensive, technically sound data base concerning the characteristics and extent of the nation's wetlands has long been recognized as a precursor to fostering wiser use of the nation's wetlands and for expediting decisions that could affect this important resource. In recognition of this need, other agencies have been providing technical and financial support to the NWI to achieve this goal.

Now that the NWI has entered into an operational mode, interagency cooperative efforts are expected to increase. These cooperative efforts will also be a major step towards resolving technical disagreements that now exist between some agencies concerning what constitutes a wetland and will lead to a better understanding of the functional value of wetlands.

"We have overcome a lot of hurdles," states John Montanari, NWI Team Leader in St. Petersburg, "and I am sure we will encounter more in the future. But, I am convinced that the wetland data base we have been mandated to develop will be delivered in an expedient and cost-effective manner. The interagency cooperation that I have witnessed on this project," he adds, "reinforces this conviction." ■

A member of the Young Adult Conservation Corps removes peel coat material from wetland polygons, enabling maps that display wetlands in a different color from uplands.

Regional Wetland Coordinators

Region	Geographical Area	Regional Wetland Coordinator
1	*Alaska, California, Nevada, Hawaii, Oregon, Washington	Regional Wetland Coordinator, US Fish & Wildlife Service, Lloyd 500 Building; suite 1692, 500 NE Multnomah Street, Portland, OR 97232 COM: 503/231-6116 FTS: 429-6154
2	Arizona, New Mexico, Texas, Oklahoma	Regional Wetland Coordinator, US Fish & Wildlife Service, PO Box 1306, Albuquerque, NM 87103 COM: 505/766-2914 FTS: 474-2914
3	Minnesota, Wisconsin, Illinois, Indiana Michigan, Ohio	Regional Wetland Coordinator, US Fish & Wildlife Service, Federal Building, Ft. Snelling (AS/BSP), Twin Cities, MN 55111 COM: 612/725-3593 FTS: 725-3593
4	Arkansas, Louisiana, Florida, Mississippi Alabama, Georgia, South Carolina, North Carolina, Tennessee, Kentucky, Puerto Rico	Regional Wetland Coordinator, US Fish & Wildlife Service, R.B. Russell Federal Building; 75 Spring Street SW, Atlanta, GA 30303 COM: 404/221-6343 FTS: 242-6343
5	Maine, Vermont, New Hampshire, New York Massachusetts, Connecticut, Rhode Island, Pennsylvania, New Jersey, Delaware, Maryland, West Virginia, Virginia	Regional Wetland Coordinator, US Fish & Wildlife Service, One Gateway Center, suite 700, Newton Corner, MA 02158 COM: 617/965-5100 FTS: 829-9217
6	Montana, Wyoming, North Dakota, South Dakota, Nebraska, Utah, Colorado, Kansas Iowa, Missouri	Regional Wetland Coordinator, US Fish & Wildlife Service, PO Box 2548, Denver Federal Center, Denver, CO 80225 COM: 303/234-5586 FTS: 234-5586
*1	Alaska	Regional Wetland Coordinator, US Fish & Wildlife Service, Alaska Area Office, 1011 East Tudor Road, Anchorage, AK 99503 COM: 907/2976-3800 x412 FTS: 399-0150

short take

BEACH INTELLIGENCE

The Yanks are Coming, North Africa—Splashing through the surf, American troops leave their small landing craft at Arzeu, near Oran. In swift, orderly fashion the smaller vessels left the giant transports in the background, and the land attacks had begun. The 500 ship convoy safely transported all allied troops to the African coastline.

by M. L. Quinn

In July 1930, the 71st Congress approved the creation of the U.S. Army Corps of Engineers' Beach Erosion Board (BEB). This new unit originally consisted of a seven-member board—civilian and military—and a small technical staff. Working cooperatively with the states, the BEB was charged with making studies aimed at "devising effective means of preventing erosion of the shores of coastal and lake waters by waves and currents." A modest research program also became part of the unit's activities.

The severity of beach erosion problems increased during BEB's first decade. To better deal with the situation, the Beach Erosion Board hired additional engineering and support personnel, until, by December 1940, there were some 20 people on the Board's technical staff. Earlier that year, the BEB had moved into a new office on the U.S. Army's Dalecarlia Reservation in the westernmost corner of Washington, D.C. At this same site was the BEB's 85-foot long experimental wave tank, constructed in 1937.

This new era of growth for the Beach Erosion Board had barely begun, however, when the nation found itself in the throes of World War II. The war quickly siphoned off many of the BEB staff, military and civilian. The question became whether the unit should continue to perform its civil functions, greatly curtailed by the war, or whether there was some other contribution it could make to the military effort. The latter course was taken, and the BEB began the phase of its history which was to make it an asset unique to the United States and to the Army Corps of Engineers during the war.

The Beach Erosion Board's senior military officer at this time was Brigadier General John J. Kingman, while Martin A. Mason was the senior civilian on the technical staff. Kingman, Mason and others speculated that the BEB staff, with its knowledge of shoreline processes and wave action, could supply useful information regarding foreign beaches slated for amphibious landings of troops, tanks, and other military equipment. In pursuit of this idea, a preliminary investigation was begun on the area most likely to be used as a beachhead for such a landing—the coast of France along the English Channel. In June 1942, a conference was held with the Military Intelligence Division of the Office of the Chief of Engineers to discuss the BEB's possible role in beach intelligence. As a result of this conference and by order of the Chief of Engineers, the BEB completed in July 1942 its first intelligence study, "Landing Area Report: Cherbourg to Dunkirk." The report came to the attention of the Joint Chiefs of Staff, and they, along with their European counterparts, quickly appreciated the enormous military value of such information. The study was promptly classified and security restrictions applied to the entire BEB staff and to all its ensuing beach intelligence work during the remainder of the war.

The road to action was now open—a road which was to entirely transform the Beach Erosion Board. Kingman and Mason, with the assistance of several of the Board

Dr. Quinn is an assistant professor of geography at the University of Nebraska, Lincoln 68583.

members, were able to secure skilled scientists and other personnel to augment their depleted staff and to advance the agency's vital military program. Among those recruited were Garbis H. Keulegan, a specialist in wave mechanics, and William C. Krumbein, a noted geologist. These four men—Kingman, Mason, Keulegan, and Grumbein-plus Jay V. Hall, who had worked for the BEB since it was established, formed the nucleus of the agency's staff during the war. They were supported by engineers, geologists, draftsmen, and librarians, plus maintenance and secretarial staff. Throughout the course of the war and for varying lengths of time, military personnel from the Allied Forces, along with scientists working on beach and wave phenomena, frequented the unpretentious facility on the outskirts of Washington, D.C., and provided additional expertise and knowledge, as well as problems to be solved.

The Beach Erosion Board's intelligence work had two main divisions of effort. One division, headed by Krumbein, involved the preparation of beach landing reports. Assignments would be received from the Strategic Intelligence Branch of the Office, Chief of Engineers. The job of Krumbein and his associates was to gather together all available information on beach sites, within the assigned region, at which military landings were being considered. This included such facts as beach slope, sand characteristics, tidal fluctuations, coral reef locations (if any), as well as wave and surf conditions. The data would then be transferred to maps of the area in question and a detailed report written, accompanied by charts and photographs. The staff usually had just one month to prepare complete reports for three designated sites, one of which was to be used for an amphibious operation. Long before the days of computerized information retrieval systems, the short preparation time for these important reports is particularly impressive.

In September 1942 the BEB staff completed a report on the coast of North Africa, from Casablanca to the vicinity of Tangiers. An Allied landing took place in the area in November of that year. This study was followed by work on Sicily and southern Italy. Beginning in 1943, attention shifted to the Pacific, with beach intelligence reports being prepared on such locations as New Guinea, the Caroline Islands, Formosa, the Philippines, and Japan.

Another related activity, which was part of this group's responsibility, was the preparation of brief, graphic reports used more for strategic planning rather than actual operations. These were requested by the Joint Chiefs of Staff usually on short order, with deadlines ranging from 24 to 72 hours. The purpose of the strategic planning reports (called "quickies" by the BEB staff) was to present, as concisely as possible, the major layout of terrain of a fairly large area, often an island or peninsula, and to indicate where men and equipment could or could not be landed.

The second division of BEB beach intelligence activity was wave research, and it was with problems of this orientation that Garbis Keulegan worked. Experiments were run almost continually in the 85-foot wave tank. The needs and conditions of war brought to BEB researchers such problems as: the beaching characteristics of amphibious landing craft; determination of water depths over offshore bars; the stability of bottom-founded magnetic mines under the influence of waves and currents; the development of movable breakwaters; and the viability of a 5000-foot long floating air field or seadrome for the refueling of planes in the mid-Atlantic.

Knowledge of the water depth along a potential landing beach was a vitally important piece of information, but one equally difficult to secure. Then it was hypothesized that depths could be determined by using aerial photography of the wave conditions at the beach site. It was known that the wavelength decreases as a wave moves into shoal water. By calculating this change in wavelength from the photos, the water depth could then be found. With the development of this technique, so useful to beach intelligence, the BEB staff became increasingly involved in aerial photography and its interpretation.

During the course of the war, the Beach Erosion Board maintained close liaison with other Federal agencies. Starting in early spring of 1944, for example, the BEB took part in a program to train personnel, largely from the Military Branch of the U.S. Geological Survey, in coast and landing-beach intelligence. After spending several months at the BEB, these men would then be assigned to various military locations, largely in the Pacific theater, to act as consultants and to gather additional data. On occasion, they were required to study a beachhead just a few days following an actual landing to determine how accurate the landing report had been, and to suggest methods for improvement.

It is an undisputed fact that, during World War II, the Army Corps of Engineers' Beach Erosion Board bore a great responsibility involving the lives of many thousands of men. The safe landing of Allied troops and equipment on some distant beachhead often hinged on the accuracy of one of the over fifty reports prepared by this small unit during the war. In recognition of its contribution to the war effort, the BEB received a number of commendations, including War Department civilian awards for staff members Martin Mason and William Krumbein. And through those long, dark years of World War II, General Kingman was the BEB's guiding light. His astute leadership won the admiration not only of his own staff but of those in other agencies involved in related intelligence work.

The years following World War II brought many changes to the Beach Erosion Board—new faces, new facilities, and a reinstated civil works program. Beach intelligence remained part of the BEB's responsibility until 1962, when it was transferred to a newly-created unit. Then, in November of the following year, the Beach Erosion Board became history, being replaced by the still existing U.S. Army Corps of Engineers' Coastal Engineering Research Center (CERC).

It is indeed appropriate that the building which now houses CERC and several other Corps units is known as the Kingman Building. The General's name is a reminder of the Beach Erosion Board's unique and vital role in beach intelligence during the Second World War ■

Weather Modification: Winners & Losers

by Stanley A. Changnon, Jr.

The weather affects everyone, directly or indirectly. Today's hailstorm may destroy your wheat crop, or a drought in California may lead to higher food costs gradually appearing a year later. When any type of weather occurs, the benefits from it are balanced by suffering. Even the extremes—droughts, floods, and major snowstorms—leave some winners in their wake. Economic benefits come to those providing specialized services such as hauling water or removing snow.

Changing the weather to achieve a benefit (more rain for crops, fewer hailstorms, more snow for runoff) will also produce some losers along with some winners. Weather modification, to be successful, must recognize this salient fact, and be developed and conducted within a societal framework that properly addresses the results from changing the weather over an area. After all, the emerging technology of weather modification (as described in the Summer 1978 *Water Spectrum),* is not an individual choice to use or reject. It is a community choice. Weather modification, even on the smallest possible scales, means changing clouds and precipitation (rain, snow, or hail) over hundreds of square miles. The nation continues to have many county-scale (500 to 2000 square mile) projects supported by local investors, but there is little

Professor Changnon heads an atmospheric sciences research group of the Illinois State Water Survey, and is on the staff of the Department of Geography at the University of Illinois at Urbana 61801.

Flooding . . . and drought—extremes of precipitation that have plagued mankind throughout his history may be lessened as we improve the science of weather modification.

scientific or technical know-how to determine exactly where, or how extensively, the attempted weather modification extends for any given cloud seeding attempt. Although the weather changes may be generally local, they will still affect many farms and thousands of people (many of whom may not be in favor of the weather modification or who are actually hurt by the change).

The scientific push in modern weather modification has naturally been in a meteorological vein. The overriding question has been, "can we do it?" The atmospheric scientists who have pursued the answer to this generally elusive goal for the past 30 years have been operating under the premise that if a change in the weather could be produced, it would be for mankind's good. Over the last few years it has become painstakingly clear that this premise was not totally correct. In fact, in the last 10 years there has been a growing awareness within the scientific community that the socio-politico-economic-environmental aspects of weather modification are as complex as the atmospheric issues. This awareness led to the inevitable conclusion that the weather-modification research and development must include these "soft" sciences as equal partners.

The first signals of the "other half" problem, often labeled "the people problem," were the conflicts that began to emerge in the 1960s in some areas where operational (non-experimental) projects were conducted. Here, typically, were situations where some group,

either a community majority or minority, perceived that weather modification was hurting their real or perceived interests. For example, in some places people believed that hail suppression efforts to help local cotton farmers (who paid for the effort) were inadvertently decreasing rain and hurting local farmers and the pasture grasses of local ranchers. Aroused local groups then sought either legal or political routes to get the projects stopped. It should be noted, however, that although these episodes have not occurred frequently, they have achieved great national exposure—helping to make the general public skeptical of the wisdom of weather modification. Notable floods in Rapid City and Los Angeles have been cited as partially the result of local weather modification projects, but no connection has been established. In the last few years social scientists have researched these conflicts sufficiently to find two important facts that cause community, or, in the case of South Dakota, a statewide debate and ultimate rejection of the widespread use of weather modification.

First, the science of weather modification was not sufficiently well established to be able to show that the attempted hail suppression might not be decreasing rain. In fact, sociologists have demonstrated that scientific uncertainty over weather modification is the single most important factor in public rejection of weather modification, even in the areas where a majority adopted (and paid for) its use.

A second important point that their studies brought out was that better public information programs involving public participation in the decision processes ("do we seed clouds or not seed them in my area?") were also essential to wise use. These decisions and information processes normal to our democratic system need to be conducted before, during, and after weather modification programs. Scientific evaluation of weather modification efforts is also a key since laymen—other than farmers, perhaps—wouldn't perceive a 15 percent rain increase or a 30 percent hail decrease.

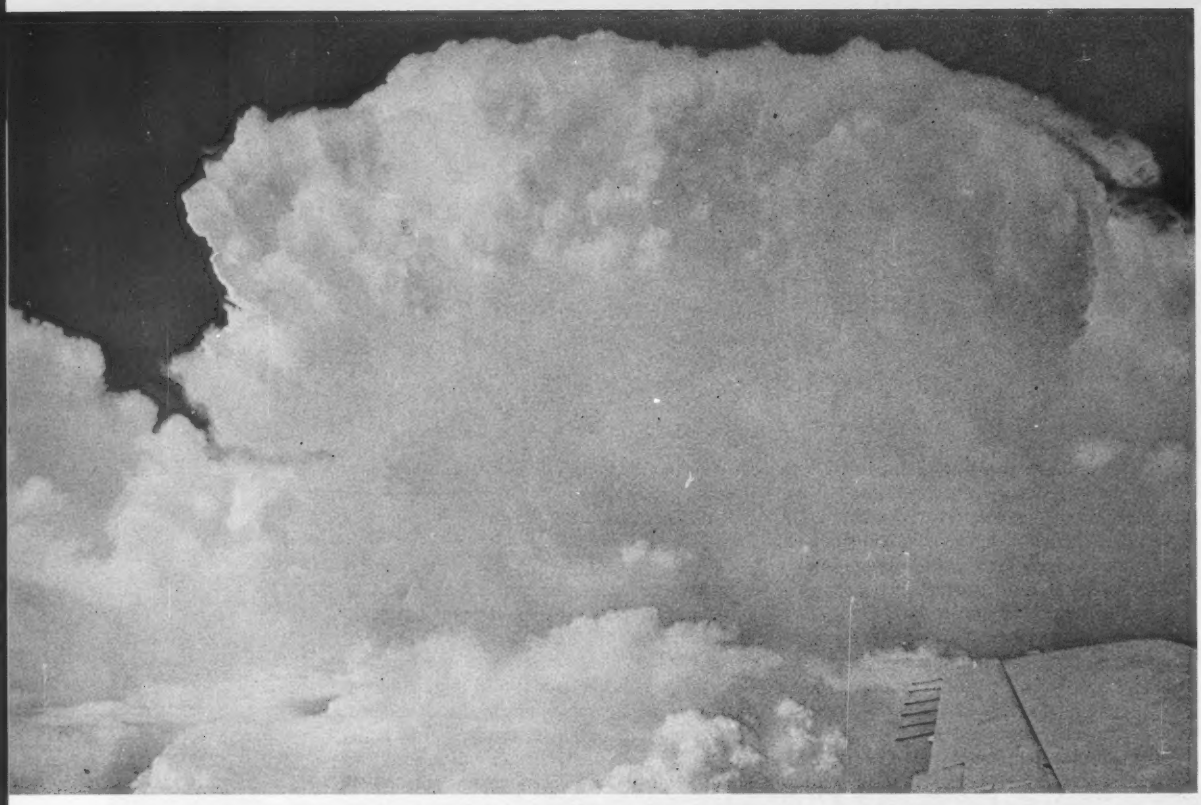
Another major aspect of the "soft science" side of weather modification relates to the evolution of the weather modification technology itself. As evidence of a capability to suppress cold fogs and to make snow in parts of the Rockies grew in the late 1960s, and as the environmental concern movement also developed, people began asking questions like, "If we really can make it rain more, whom will it hurt?" or "Will more snow in the mountains hurt the elk herds?" The issues led to a general question, "What kinds of harm and conflicts can, or will, or could develop in an area employing weather modification?"

Unfortunately, there were few solid answers to these and the many similar questions being asked in the 1960s. Nevertheless, government sponsored weather modification research continued, with those involved largely unaware of the need to address these societal and environmental questions and issues. Fortunately, new actors in this now complex drama began to appear, with new faces from the social and environmental sciences.

New Players in Weather Modification

The lawyers got involved early when conflicts about weather modification brought lawsuits. For example, intense local conflicts about hail suppression efforts in Pennsylvania and West Virginia led to the passage of state laws that essentially restrict any future use of weather modification. Western states passed certain weather modification laws, but these were often of little value because of their lack of understanding of both the scientific and "people" issues.

By the early 1970s, more comprehensive state



This cloud at 45,000 feet has just undergone seeding with silver iodide.

laws—both to control and monitor weather modification and to promote public participation—were developed as the science became better understood and the public concerns became more definable. New state laws in Texas, Colorado, and Illinois have shown the way toward competent, legal, state-level management of weather modification but do not address the issue of water rights. The Federal government had stayed out of the weather modification control arena, and established only reporting requirements for weather modification activities during the 1960s. In 1976 a new Federal law was signed, requiring that the Department of Commerce develop a national program for weather modification in one year and submit it to the President and Congress. At presstime, this much-delayed report has not been submitted by DOC although the Weather Modification Advisory Board, appointed by DOC to write such a program plan, finished its major report in July 1978.

Political interest and concern in the field has always been present, generally with Congress supportive of R&D in weather modification and the Administration being less interested and low key about the science. Congressional interest took on a negative aspect when reports of the use of rain making in Vietnam appeared. This raised the issue of the international use of weather modification in warfare, and has subsequently led to an almost total withdrawal of Defense Department support of research in weather modification. The primary Federal agencies currently supporting research in weather modification are the Department of Interior (Bureau of Reclamation), the Department of Commerce (National Oceanic and Atmospheric Administration), and the National Science Foundation.

Economists also became involved in weather modification. Modeling of economic impacts and related data gathering were begun in the late 1960s and led to the first serious economic studies of weather modification. However, this

How a northwestern Kansas farmer's net income for wheat production would change due to various degrees of postulated hail and rainfall modification.

Percent reduction in crop-hail damage	Percent change in growing season rainfall	Average net income per harvested acre (dollars)
0	−10	21.56
0	No change	24.58
0	+10	27.31
20	−10	22.60
20	No change	25.74
20	+10	28.47
50	−10	24.34
50	No change	27.35
50	+10	30.11
80	−10	25.98
80	No change	29.11
80	+10	31.88

Annual average national additional production of selected commodities and goods, based on 10 percent additional precipitation and 30 percent reduction in hail damage during critical periods in main production areas (National Resources Council, 1976).

Crops/Goods	Additional Quantity Produced (× 10)
Corn	
Added precipitation	38.0 bu
Reduced hail	8.4 bu
Total	46.4 bu
Wheat	
Added precipitation	34.0 bu
Reduced hail	30.6 bu
Total	64.6 bu

Crops/Goods	Additional Quantity Produced (× 10)
Soybeans	
Added precipitation	18.4 bu
Reduced hail	4.7 bu
Total	23.1 bu
Western range	
Forage	52,500 lb
Range cattle	4,375 lb
Irrigation water	
Added orographic snowpack	10.0 acre-ft

is still an area requiring more research.

Sociologists also began to study certain areas of weather modification, essentially by asking comprehensive questions of people in weather modification areas. Their studies have recently established profiles for different parts of the nation as to public beliefs and attitudes about modification, and have helped to clarify several critical societal aspects therein.

Ecologists were another group of "outside actors" to become involved in weather modification in the late 1960s. They focused on the impact of altered precipitation on the ecosystem. These efforts have suffered, however, as in economic research, by the lack of quantified information about how weather actually affects environmental systems. The environmental investigations also addressed the political impacts of the cloud seeding agents, such as silver iodide, on the environment. Dry ice is the other major seeding agent; experiments have also been conducted with urea.

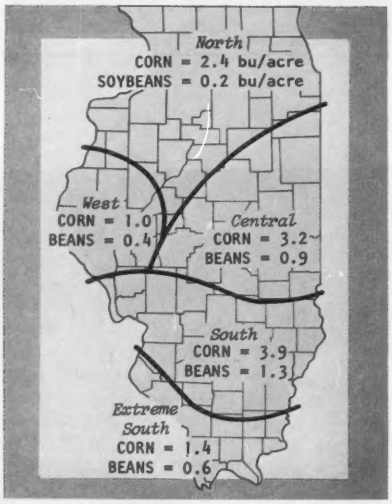
Weather modifiers must deal with the environmental impact on big game herds when mountain snowpacks are increased.

Comprehensive Impact Studies

Two weather modification research projects outlined here were notable pioneering efforts in addressing weather modification in a comprehensive way.

In the 1960s, the Illinois State Water Survey initiated a series of weather modification projects in the belief that weather modification would eventually be attempted in Illinois and the Midwest. The Survey concentrated on the design of hail suppression and rain enhancement experiments to answer the dual question, "Can we, and should we, attempt to modify the weather?" Thus, a key element in the overall program was the inclusion of environmental, economic, societal, and legal concerns. For instance, Illinois then had no state law relating to weather modification, and Survey scientists, in conjunction with legal experts, developed a model state law enacted in 1973. Environmental research into weather effects on game animals and insects was undertaken; a public attitude survey was conducted; and economic studies were made—one dealing with agriculture and the other with water resources.

AVERAGE YEARLY YIELD INCREASE FROM 25% SUMMER RAIN ENHANCEMENT



Rainfall enhancement at certain periods in the growing season, coupled with precipitation suppression at less desirable times, can have a marked effect on crop yields.
(Courtesy of Illinois State Water Survey)

The National Hail Research Experiment (NHRE) was started in northeastern Colorado during 1972 in a major national effort to conduct a hail suppression experiment within a framework of physical meteorological studies. Much of the Federal funding to the National Center for Atmospheric Research (NCAR) and universities was directed to the conduct of field experiments involving aircraft, weather radars and other sophisticated equipment. However, funds were also allocated by NCAR for an all-important effort dealing with societal and environmental issues. These included the sampling of public attitudes in and around the experimental area; the formation of a public information system; studies of the potential impacts of silver iodide on the environment; and economic studies of the impact of losses caused by hail in the region.

Growing national concern in the 1960s with how to cope with new technologies led to development of several methods to examine and assess societal impacts of new technologies. One of these methodologies, called "technology assessment," has been employed in two recent extensive weather modification assessments. In one, the Stanford Research Institute conducted a technology assessment focusing on the values and effects of snowfall enhancement in the Upper Colorado River Basin. More recently, the Illinois State Water Survey conducted a technology assessment of hail suppression involving its atmospheric scientists and social, legal, economic, and environmental experts from around the nation.

Both of these assessments provided relatively useful in-depth looks at the complexities of issues relating to weather modification. For example, the hail suppression assessment (*Hail Suppression: Impacts and Issues, Changnon et al 1977)* points to the fact that for hail suppression to be socially acceptable, the technology will have to have a scientifically supported capability and be able to suppress 50 percent or more of all hail losses. Even with hail suppression capabilities of up to 80 percent by 1995, adoption of hail suppression is predicted to occur only in the great plains, with hail insurance a more viable option for addressing hail loss in the eastern half of the United States. Another key finding shows how the net income would vary for a Kansas wheat farmer for various postulated levels of hail suppression and simultaneous rain changes (increases or decreases). First, the rainfall, along with efforts to reduce hail, will

vary considerably the farmer's personal income around the "no weather change" of about $24 per acre. A 50 percent hail decrease accompanied by a 10 percent rainfall decrease would not help him, but an 80 percent decrease in hail and a 10 percent increase in rain would be very valuable, worth about $7 per acre, or a 30 percent increase in gross income. In Kansas (and most areas at the margin of adequate rainfall), crop production is much more sensitive to minor rainfall changes than to sizeable hail reductions. These technology assessments illustrated the types of socio-economic evaluations so desperately needed in developing governmental policy about local, state, and Federal involvement in weather modification research, use, and control.

Environmental Issues

Any effort to modify the weather to better serve human needs has an "environmental impact." The protection of nature from man, a philosophy of resource management to minimize waste, became the dominant ethic in the 1960s.

Assessing biospheric impacts resulting from weather changes is complicated by an environmental data base that lacks cause-effect hypotheses. Very little effort has been devoted in the past to collecting and organizing meaningful data on environmental changes that could result from weather or climate changes.

The environmental effects of weather modification may be both beneficial and adverse. Hydrologists can recognize and even predict with their models some of the outcomes of altered precipitation quantity, frequency or intensity. There could be increased forage production that benefits both domestic livestock and herbivorous wildlife, while at the same time adversely impacting the habitats of some other animals or contributing to the demise of an endangered species.

Some of these effects may never occur, and we know that most will not be identifiable until weather changes have persisted for many years. We do not yet have the ability to accurately forecast the magnitude of these environmental impacts over the long term, which is what really counts. Nor have we developed the technical competence at this point to make satisfactory estimates. However, environmentalists who have seriously considered weather modification suggest minimal measureable effects for most short-term (5-year or less) weather changes.

Increased rainfall might encourage forage production that benefits both domestic livestock and herbivorous wildlife, while at the same time adversely impacting on the habitats of other animals.

Since the beginning of cloud seeding in the 1940s, silver iodide has been used as the seeding agent in most programs. While there are uncertainties about the potential long-run environmental impacts of silver iodide, the evidence seems to indicate that any adverse effects would be long-term, selective, and subtle. Silver-iodide seeding represents an imperceptible environmental hazard at this time.

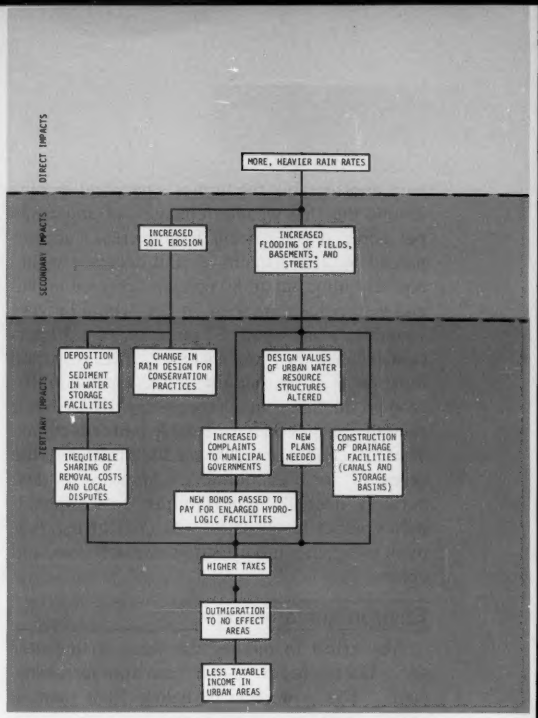
Economic Issues

In seeking to estimate and evaluate economic benefits, one finds little comprehensive data on regionwide weather-economic relationships. It is difficult to make economic assessments of weather modification in conventional benefit/cost terms when both physical capability to modify the weather and the period when the capability reaches operational status are uncertain—and are themselves partially dependent on the level and quality of the research

investment. Not that the situation is unique—very few of the technological achievements that have sparked the economic growth of the United States would have stood the test of a static benefit/cost study in the first tentative stages of their development. Serious study of the socio-economic aspects of weather modification has, hence, been limited. The better studies have considered the presumed costs, including the R&D, as well as the benefits.

The more authoritative studies, have, however, given general dimensions to the economic impacts of various potential modification capabilities. These studies reveal that the economic sector that will benefit most from a weather modification capability will obviously be agriculture. The single most valuable change in the foreseeable future is more growing season precipitation, especially at opportune times.

Basically, if agricultural production were increased by weather modification, all food consumers in the United States would be beneficiaries. The overall impact would tend to be anti-inflationary. However, changing the weather could produce a complex series of impacts providing benefits to many, and losses to other sectors of the economy such as construc-


DIRECT IMPACTS
SECONDARY IMPACTS
TERTIARY IMPACTS
MORE, HEAVIER RAIN RATES
INCREASED SOIL EROSION
INCREASED FLOODING OF FIELDS, BASEMENTS, AND STREETS
DEPOSITION OF SEDIMENT IN WATER STORAGE FACILITIES
CHANGE IN RAIN DESIGN FOR CONSERVATION PRACTICES
DESIGN VALUES OF URBAN WATER RESOURCE STRUCTURES ALTERED
INEQUITABLE SHARING OF REMOVAL COSTS AND LOCAL DISPUTES
INCREASED COMPLAINTS TO MUNICIPAL GOVERNMENTS
NEW PLANS NEEDED
CONSTRUCTION OF DRAINAGE FACILITIES (CANALS AND STORAGE BASINS)
NEW BONDS PASSED TO PAY FOR ENLARGED HYDROLOGIC FACILITIES
HIGHER TAXES
OUTMIGRATION TO NO EFFECT AREAS
LESS TAXABLE INCOME IN URBAN AREAS

The myriad impacts produced by urban modified weather at St. Louis, and specifically those attributed to locally increased summer rainfall and storms (from Summary of METROMEX, Volume 1: Weather Anomalies and Impacts).

Water-oriented recreation can be enhanced through proper amounts of precipitation, at proper times.

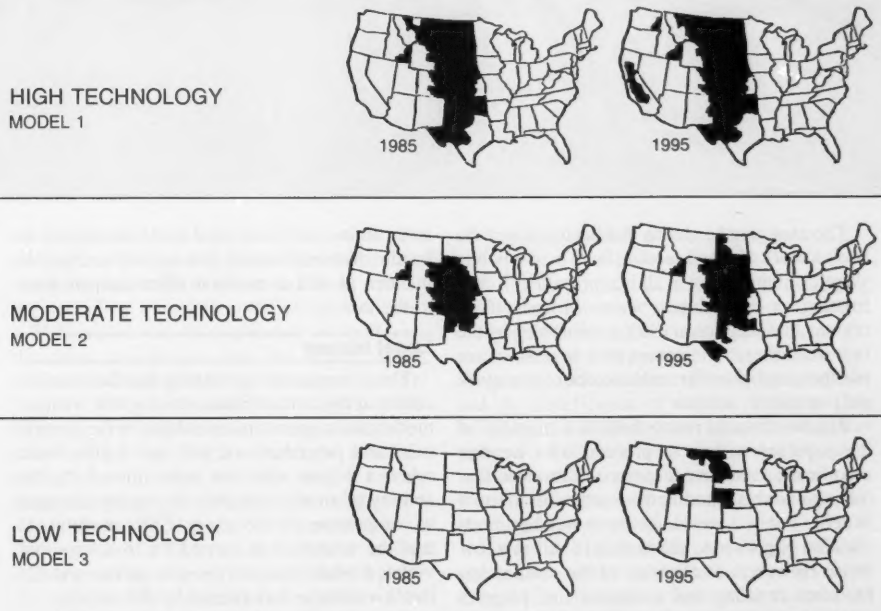
tion or tourism. A 10 percent increase in precipitation in regions of major crops (corn, wheat, and soybean) has been estimated to increase farm receipts by over $200 million *(Climate and Food,* National Academy of Sciences, 1976).

The hydrologic consequences of precipitation enhancement appear important. For example, one scenario—based on measured snowfall in the Colorado River Basin—would result in a benefit of $30 million, and in another scenario, only $12.8 million. Additional water from snow augmentation in the western United States' mountains is expected to cost about $1 per acre foot. Costs of providing additional water are about $50 per acre foot for interbasin transfers of water. Most scientific evidence suggests that increased precipitation in one area does not produce a comparable decrease in another area, although the issue is as yet unresolved scientifically.

The Weather Modification Advisory Board, in its 1978 assessment of whether the nation should develop weather modification, made key points about the economic aspects of weather modification. Weather modification will likely not make revolutionary additions to usable water supplies (or eliminate hail or hurricanes), but the potential net gains appear large enough to make weather modification one of the parallel research tracks of the United States. Further, it seems particularly important to keep our long-term options open in view of some highly attractive features of weather modification on the cost side. Operating costs of cloud seeding are very small, about 5 to 50 cents per acre, and the capital equipment is neither excessively costly nor specialty-limited to a single use or area. As a short-term, highly flexible measure to meet some of our water demands and weather hazards, weather modification could become a most useful tool.

Societal Issues

The prevailing perception in the United States is that a great deal of social controversy is generated by weather modification. However, most projects in the United States have not engendered organized opposition, and such local controversies which have arisen are widely publicized rather than widespread. Most projects have received local public support *(The Management of Weather Resources,* Department of Commerce, 1978).



The areas predicted to adopt hail suppression in 1985 and 1995, on the basis of three future technological models, each assuming varying capabilities for hail suppression and modification of rainfall (from Hail Suppression Impacts and Issues).

The exaggerated claims that accompanied the early history of cloud seeding have bred a public skepticism that is not at all inappropriate in confronting an early stage science. In agricultural regions, the skepticism is often reinforced by the fact that there are sometimes losers—since weather conditions favorable to one crop may be unfavorable to another.

Results of social research show a majority of the populace willing to proceed with weather modification and an acceptance of the idea that man should try to modify the weather for his own benefit. Public knowledge about weather modification is growing, although it is still at a low level. However, as the state of the science approaches certainty and evaluations of projects establish the degree of weather change, new problems will emerge in that proof of damage caused by modified weather will then be possible. The ensuing legal conflicts will be unavoidable. Rules will then need to be developed to handle the controversies in a socially acceptable manner, as well as means to offer compensation to the losers.

Legal Issues

The common law governing weather modification in the United States reveals that weather modification operators are subject to the general rules and procedures of tort law. Under these rules, a person who has been injured by the activity of another can recover money damages to compensate for the injury if he can show (1) that the activity was carried on in a way that violated established norms of conduct, and (2) that his damage was caused by the activity.

To date, only a dozen damage actions have been brought against weather modification operators. None of the actions has succeeded, although two are still pending. The problem in

Additional water from snow augmentation in the western mountains can drastically lower the costs of interbasin transfers of water into arid areas.

every case has been proof in causation; the plaintiff has been unable to show that the harm he complains of would not have occurred without the defendant's weather modification activities.

If causation can be established in the future, the courts will have to face the second, as yet unanswered, question of what theory of liability to apply. There are essentially two choices: liability only for fault—that is, damages caused by some negligent or otherwise wrongful act of the defendant; or absolute liability—that is, for any harm caused by the defendant, no matter how careful he is. Since modern tort law, overall, is moving from a fault to an absolute liability (risk-spreading) theory, it seems unlikely that this trend will be resisted in the weather modification field. One would expect, therefore, that most states will adopt the absolute liability standard, or some other mode of shifting a larger burden to the defendant. Federal experimental activity is essentially without legal control.

Summary

The use of weather modification continues in the United States amidst considerable scientific uncertainty and occasional local controversy. Weather modification is relatively inexpensive, and the modification of weather, either to gain added benefits (higher crop yields or more power generation) or to decrease losses due to severe weather, continues to lead people to seek and use this art, science, or emerging technology, depending on your point of view.

However, I think it has been clearly demonstrated that weather modification, as a scientific exercise and economic enterprise, cannot go forward in a wise or healthy fashion without being placed in a comprehensive framework that embraces everyone potentially affected. ■

At left is a test lighthouse in Finland that incorporates new research findings in its design. At right is the traditional configuration. The bases are two and six feet, respectively. An important aspect of CRREL's ice engineering work is in the area of interaction between man-made structures and surrounding ice fields.

ICE ENGINEERING

by David A. O'Steen

If you were responsible for a public boat dock destroyed by ice in northern Michigan, you would be pretty upset at what the forces of winter have done. You might know that the water level rising underneath the ice cover caused the ice to rise and bring with it the piling supporting your dock, but where could you go to find a solution to the problem? You might call the local District of the U.S. Army Corps of Engineers, who in turn might call the the Corps of Engineers Cold Regions Research and Engineering Laboratory in Hanover, NH (CRREL), commanded by Colonel Alfred B. Devereaux, Jr. For it is at CRREL that experts in ice and ice engineering go to work on problems such as this.

History

Ice engineering as a discipline actually began in the 1920s but accelerated in the mid 1960s when there was a strong push to test the feasibility of using the Northwest Passage to move oil from Prudhoe Bay to the Atlantic Ocean using ice-breaking tankers. CRREL sent a five-man team with the SS Manhattan on its historic voyage in 1969. Part of CRREL's mission during the voyage was to determine design criteria for a new generation of icebreakers capable of making the run from Prudhoe to the Atlantic year-round. Prior to that time the ice engineering research conducted at CRREL was largely confined to testing the strength of ice covers under various conditions with a view towards determining the tactical military value of the ice cover.

Shortly after the Manhattan mission was completed, interest in extending the navigation season on the Great Lakes and on the St. Lawrence Seaway began to grow and resulted in the 1970 Congressionally authorized three-year action program to demonstrate the feasibility of extending the navigation season on these waters. At the beginning of the program several major problems had to be addressed: Since ice is the

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Mr. O'Steen is a Program Analyst with the U.S. Army Corps of Engineers' Cold Regions Research and Engineering Laboratory in Hanover, New Hampshire 03755.

The pier pilings here have been lifted by the ice cover as the water level rose beneath the ice. Such winter damage along the shores and rivers of the Great Lakes is common. (Photo by Zabilansky, CRREL)

major impediment to winter navigation on the Great Lakes, what will we do to break it up? Once the ice is broken, how will we control the ice floes that will be carried into the restricted channels connecting the Great Lakes? Ice-clogged connectors such as the St. Clair River between Lake Huron and Lake Erie, the St. Marys River between Lake Superior and Lake Huron, and the Straits of Mackinac connecting Lake Michigan and Lake Huron make the Great Lakes route impassable. Icebreakers will be able to open vessel tracks, but ice management techniques must be developed to keep the routes open. Stable ice fields are essential to smooth operation during the ice season.

A solution was conceivable, of course, but how was it to be tested without going to enormous expense to install a prototype that might have to be modified year after year until it was satisfactory? Clearly the Corps needed a new facility, one in which model tests could be run to simulate actual ice conditions at for example the southern end of Lake Huron.

It was not enough to construct a rough model of the area and push water through it. There were too many dimensions to consider, and, for a reasonable chance of success, all possible variables at work had to be studied. What was needed was a laboratory large enough to house scale models of problem areas, complete with an accurate topography of the water bed. Nor was it enough to test various ice boom designs and positions with plastic floating pieces simulating natural ice floes. What was needed was a refrigerated laboratory capable of testing ice control structures with real ice.

CRREL engineers prepare the flume for tests designed to measure the forces of an ice cover against the shores of a river. Once the instrumentation of the test area is complete, they will lower the temperature in the flume and test with real ice, not the plastic floating pieces visible in the background. (Photo by Demars, CRREL).

A team headed by Guenther Frankenstein, now Chief of the Ice Engineering Research Branch at CRREL, began to assemble plans for the new ice engineering facility so important to the success of the Great Lakes winter navigation program. After visiting hydraulic modeling facilities in several parts of the world (such work is also performed in Finland, Germany, Russia, and Canada), the team put together its plan for the facility. Plans called for a large *research area* for physical hydraulic modeling work such as must be done for the Lake Huron/St. Clair River problem. The planning team also wanted a *flume* (an inclined channel used to simulate a river), so that the lab could study the formation of ice covers. And finally the facility would contain a *test basin* in which to measure the forces of ice moving against a structure in an ice field. All three of these rooms were to be refrigerated so that the temperatures could be brought down to −10°F. And, of course, there had to be a power plant large enough to cool all three areas simultaneously.

The building which emerged from these criteria—the current Ice Engineering Facility at CRREL—took three years to build and was

One of the most versatile areas of the Ice Engineering Facility at CRREL is this research area, where temperature ranges of 65 to −10°F are possible. Models of problem river reaches are constructed here to test ways of alleviating ice jams. Tests of the bearing capacity of large ice sheets and cold-testing of vehicles and small structures are also possible.

A model of the southern end of Lake Huron, complete with real ice and a scale model ore carrier, is tested in the research area. Testing is designed to measure the amount of ice discharged through the opening in the ice boom whenever an ore carrier moves through. (Photo by Atwood, CRREL).

dedicated formally in April 1979. The building won honorable mention in the Chief of Engineers 1978 Design and Environmental competition.

Research Area

The largest of the three main work areas in the Ice Engineering Facility is the *research area*. Measuring 80′ by 160′, the research area is the only refrigerated hydraulic modeling laboratory in the world. The main advantage of refrigeration, of course, is that investigative work can be carried out using real ice, not pieces of floating plastic commonly used in non-refrigerated laboratories. The expanse of the research area permits researchers to build scale models of river reaches and adjacent flood plains miles long. Once actual topographical measurements of the water bed are taken in the field, CRREL engineers mold a scale model of the area using concrete as the main construction material.

In view of the original justification for the CRREL Ice Engineering Facility, it is not surprising that the first modeling project in the research area is for the study of ice control structures to be installed at the southern end of Lake Huron where the lake empties into the St. Clair River. The main purpose of the ice control structure is to prevent ice from going into

the river and thus prevent ice jams and flooding. The secondary purpose of the ice control structure is to allow winter navigation to continue without letting too much ice bleed through the opening required for ships to transit. In the research area are two models: a hydraulic model of the southern end of Lake Huron, and a model to investigate the behavior of broken ice cover under the influence of the wind. The flow of water is not the only force moving ice downlake to the head of the river. In that area northerly winds may also put a considerable load on the ice control structure. The effect of the wind is simulated in the laboratory by a uniform flow of water underneath the floating ice which is contained in place by the instrumented boundary segments hanging from above.

Dr. D. S. Sodhi, research engineer working on the project, explains: "Using the flow of water in the model creates a uniform shear stress on the ice cover similar to that of the wind on ice floes. What we are most interested in is the force interaction of the ice floes against the shore and the ice booms. Our experiments are set up to optimize the configuration of the ice control structure with respect to ice forces and the ice bleeding during a ship's passage through the opening."

Darryl Calkins, another research engineer working on the Lake Huron model, is very encouraged with results so far. "We have been able to simulate the re-arching phenomenon of floating ice at an opening in an ice control structure due to ship transits. In other words, we have been able to measure the volume of ice passing through an opening each time a vessel passes. This information will aid the Corps' Detroit District in analyzing the reduced ice conditions in the lower stretches of the St. Clair River." The modeling project will be finished by the spring of 1980.

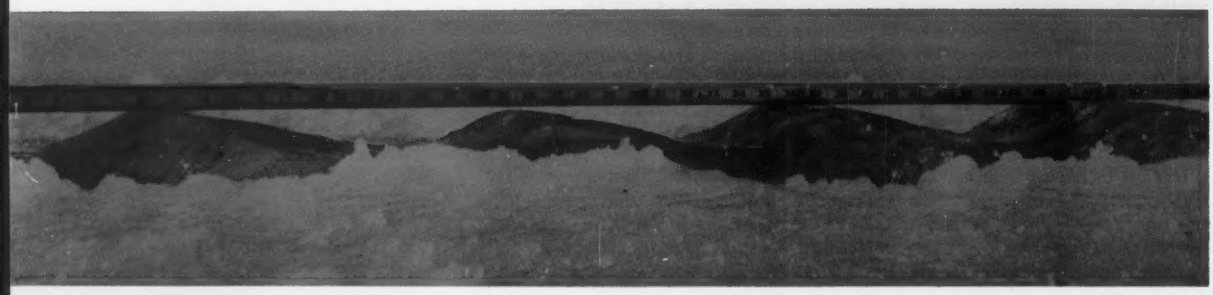
Once the Lake Huron project is completed, the research area will be cleared and two hydraulic models of the Ottauquechee River in Vermont will be built for the study of ice jams. The Ottauquechee River is plagued with ice jams and serious flooding every year. Because of the complexity of the Ottauquechee's ice dynamics, that river is a particularly good one to study. The feeling among CRREL engineers is that the lessons learned from the Ottauquechee study will greatly enhance the implementation of effective ice control measures in practically any ice-prone river system in the world, particularly in the area of preventing and coping with ice jams.

The research area is also well suited for hydraulic models to study spillway icing problems, how to pass ice through man-made structures, and how to navigate in ice-clogged channels.

Flume

Like the research area, the *flume* is remarkable for its versatility and its unique experimental capabilities. The flume allows the study of ice sheet formation. Most people only see the top of an ice sheet, which appears to be smooth. Not many people have ever seen the bottom of an ice sheet which can be wavy just prior to breakup due to the action of warm flowing water. The flume has a refrigerated bottom which permits researchers to grow an ice sheet from the bottom upwards instead of from the top down as normally occurs in nature. What we have then in the laboratory is an ice sheet turned upside down.

This photo of an ice slab from the Cedar River in Iowa, shows a typical pattern of fully developed ripples caused by the turbulent flow of warm water beneath the ice cover.



Another particularly important research capability provided by the flume is the study of *frazil ice*, the sticky particles of ice generated in supercooled water. When frazil accumulates on an object in the water, it takes on a mushy appearance and resembles a snown cone. Frazil ice is largely responsible for flooding due to "hanging dams," the accumulation of frazil ice underneath an ice sheet on a river or stream. The dam blocks the water flow and leads to flooding as the water behind the jam backs up. Floods in this country cause millions of dollars of damage each year. Ice jams interrupt river navigation, and the reduced flows due to frazil ice accumulations at water intakes cause severe reductions in hydropower output. Success in the flume means a tremendous continuing economic benefit to the country in terms of damage dollars saved through effective ice control measures.

Research carried on in the flume includes work on ice booms to contain frazil ice. CRREL headed up successful ice boom design work on the St. Marys River and now is evaluating an ice boom with strands of material to "grab" the frazil ice particles as they are carried downstream by the flow of water. Other research in the flume has produced a promising design for structures to protect water intake devices from frazil on the bottom of frozen rivers. Such intakes are vital for many industrial cooling systems, and their failure due to frazil normally means factory shutdown until the water intakes are unclogged. Other CRREL engineers are working in the flume to measure the forces exerted by an ice cover against the shoreline of a river. This research will lead to more effective shoreline protective measures and will reduce the annual losses caused by ice moving against shoreline property.

The Test Basin

The third major research room in the Ice Engineering Facility at CRREL is known as the *test basin*. Measuring 30′ wide, 120′ long, and 8′ deep, the test basin was designed primarily for large scale work on ice forces on structures built in ice fields. Bridge piers, lighthouses, and drilling rigs all have special design requirements, and the effect of ice forces must be considered. Dr. Mauri Maattanen, a research engineer from Finland, is using the test basin to measure the forces of an ice sheet as it moves against various types of pilings. The work is jointly sponsored by the Finnish government and the Corps of Engineers.

Dr. Maattanen has pioneered in the investigation of the interaction between the natural vibrations of a given structure and the vibrations inherent in a sheet of moving ice. If special vibration dampers are incorporated into the structure, lighthouses can be built slimmer and still can withstand ice forces. The cost of construction may be reduced since there is no longer any reason to overdesign.

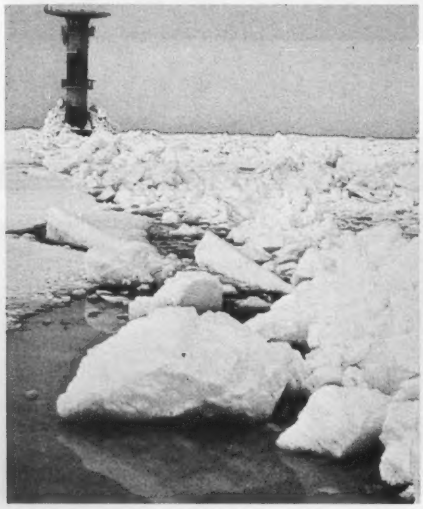
Underwater windows on the bottom and on the sides of the test basin, together with underwater lights, permit observers to see what is happening under the ice. Underwater windows also provide a means for dry underwater photography. Plans are now underway to conduct model tests of Corps vessels to determine their potential for helping to control river ice.

CRREL engineers test the effects of an ice sheet moving against a man-made structure in the test basin. The basin also has fill and drain capability at each end so that studies can be made with water level changes such as at locks and dams. Other tests possible in the test basin involve the formation of ice pressure ridges and vertical uplift forces.

This test basin ice is being pushed into the melt tank at the end of the basin. While it melts, a new ice cover can be grown and experiments continued on a daily basis. The test basin is designed primarily for large-scale work on ice force interaction with structures such as drill platforms and bridge piers, and for work on lockwall deicing.

The Mississippi River at Mile 60, showing the upper end of a track made by a tow moving through an ice sheet.

At left is a lighthouse in Finland's Gulf of Bothnia. The broken ice is the result of an ice sheet moving against the structure. The sheet is about three feet thick and is largely wind-driven. The laboratory photo at right shows CRREL research engineers at work on the same phenomenon.



The electrically driven carriage which stretches across the test basin moves on rails the entire length of the pool. Precision engineered for controlled speeds, the carriage is used to push the ice sheet along the basin and into the structure under investigation. Speeds range from ½ foot per second to seven feet per second, allowing model testing of a wide range of actual speeds.

Perhaps one of the most important uses of the test basin is to study the formation of ice along the walls of a lock used for navigation on domestic waterways. It is common to find ice up to several feet thick on both sides of many lock chamber walls in the northern areas of the country. The reduced width of the chamber forces the towboat operator to reduce the width of his tow. In many cases this means a 30-50 percent reduction in the towboat's efficiency, which is very costly to shippers and ultimately to consumers.

A striking example of this problem occurred in February 1978 at Markland Lock and Dam on the Ohio River between Louisville and Cincinnati. As a towboat pushing two 54′ wide oil barges abreast (for a total width of 108′) tried to enter the main lock, the barges became lodged in the lock chamber because of ice buildup on both lock chamber walls. An emergency situation developed when gasoline began to leak from the pinned barges. It took several days to free the barges from the lock chamber and for that time traffic at that point in the river was completely halted.

Work in the test basin will focus on ways to fight the adherence of ice to lock chamber walls using various means: chemical coatings, application of heat, and mechanical methods of ice removal. Significant progress has been made with chemical coatings to reduce ice adhesion to lock chamber walls at Sault Ste. Marie, Michigan and at Lock and Dam 21 on the Upper Mississippi. CRREL's Ben Hanamoto has headed up the work with coatings and has just completed coating Army and Air Force antennas in New Jersey and in Nebraska. There is also strong interest overseas in the CRREL coatings. Engineers from CRREL have been asked to consult on ice problems at canals and locks in Holland, northern Germany, and Sweden. High velocity air screens have also proven effective in controlling ice floes at navigation locks, and the test basin is ideal for refining air screen design.

The test basin is also used to study the problem identified in the beginning of this article: that of the uplifting force of ice. Leonard Zabilansky, a research engineer specializing in this area, has formulated a design for the construction of vertical support pilings. Zabilansky proposes at least two ways of protecting dock and pier pilings from being destroyed by the ice cover: (1) encase the piling with a cylinder that will rise with the ice, leaving the bearing piling untouched, and (2) covering the piling with a special coating which permits the ice to slide up the vertical as it is raised by the water. Both methods have proven effective at

test sites, news of these construction techniques is spreading fast. The techniques are cost-effective, and many dock owners plagued with this problem every year may soon adopt the methods.

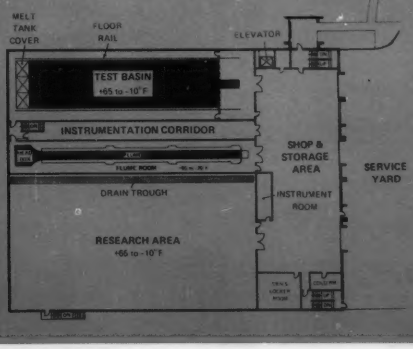
The Power Plant

An article on the Ice Engineering Facility at CRREL would be incomplete without mention of the unique use of the giant refrigeration system to heat the building. Relying on the use of two heat pumps, the heat drawn out of the laboratory cold rooms is circulated through the shop area and the administrative office area. The heat drawn out of the cold work areas would ordinarily have been wasted, but the heat pumps have enabled the facility to take advantage of the waste heat. This is a particularly significant development in these times of energy conservation. Waste heat is also used for melting the experimental ice and snow. If for some reason there is no waste heat available from the laboratory areas, the heating system creates an artificial demand for refrigeration by chilling well water from 48°F to 39°F. When it is time for air conditioning, the system makes use of well water which is available in large quantities at temperatures of about 48°F. The use of waste heat in the Ice Engineering Facility should be roughly one-third the cost of a conventional oil heating system, and at least $10,000 was saved during construction by the decision not to install a conventional heating system.

The Future

Engineers at the Ice Engineering Facility at CRREL are confident of proving its value in terms of service to the Corps and the nation. Work performed there has resulted in the development of numerous cost-saving measures to make life easier for those who must work in cold environments. From high velocity air screens at Corps locks, to wall coatings on lock walls, to ice booms on the St. Lawrence, to ice jam prevention and removal procedures, the Ice Engineering Facility at CRREL is dedicated to being of service. Its customers already include Corps Divisions and Districts, other Department of Defense agencies, other Federal agencies, and state and local governmental agencies. As the field of ice engineering matures, there is no doubt that the demands placed on the facility will lead to greater and greater strides toward the goal of increasing the operational capabilities of the Corps of Engineers and of the Army in regions afflicted by severe winters.

As Colonel Devereaux says, "One of the most important fields of engineering today has to be ice engineering. Over 120 million people in the United States live in ice-prone areas, and over 1½ billion people in the world must cope with ice in their daily lives during the winter. With the growing worldwide responsibilities of the Corps of Engineers, CRREL's new facility provides it with a unique capability to be of service." ■



The floor plan of the Ice Engineering Facility at the U.S. Army Corps of Engineers Cold Regions Research and Engineering Laboratory in Hanover, N.H.

Ironically, the world's oceans may someday provide our drinking water. (CofE Photo)

DESALTING: AN OFFER YOU MAY NOT REFUSE

by William H. McCoy

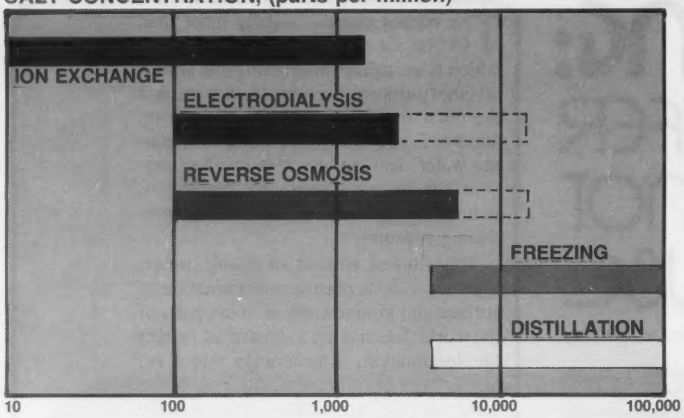
The oceans contain slightly more than 97 percent of the Earth's water, all of which is too saline for drinking and almost all other purposes. Less brackish water and the polar regions' frozen water make up another 2.5 percent of the Earth's remaining water, leaving less than one-half percent for use and reuse by municipal, industrial, agricultural, and energy-producing consumers.

This limited amount of usable water, together with increasing contamination of surface and groundwater in many parts of the world, has created a substantial market for desalination, a technology which removes salts and other minerals from saline and impaired waters. Although technically feasible, desalting is still relatively costly even after years of research and development. Much of that research began with the Federal Government's Office of Saline Water in 1952. This group was integrated into the Office of Water Research and Technology (OWRT) in the U.S. Department of the Interior, and overseas programs to improve desalination technology while reducing costs.

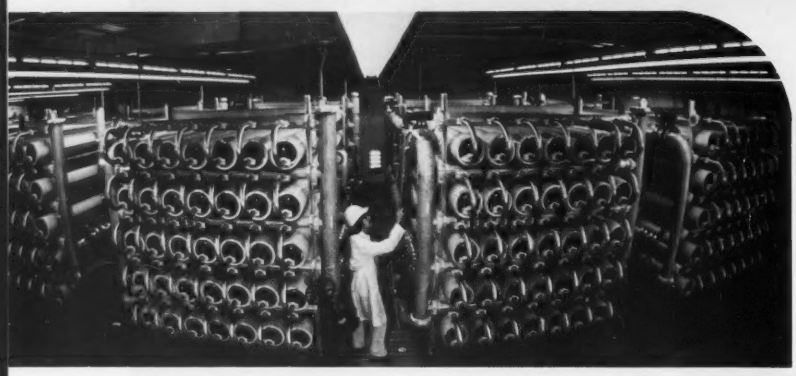
The Earth's freshwater supply is shrinking on a per capita basis as a result of population growth and increased mineralization and pollution of rivers, lakes, and underground reservoirs. In urban areas, population growth adds large amounts of wastes, including salts, to surface and groundwaters, making downstream waters less desirable for potable supplies. In coastal areas, fresh water is withdrawn from the ground faster than it can be naturally recharged. When seawater fills the void, the usual result is a groundwater supply too brackish for most uses. In agricultural areas, irrigation water not used by plants moves through the soil, carrying salts and minerals which eventually reach groundwater aquifers, rivers or lakes. Waste chemicals and acid mine drainage can add to the general problem.

Public Law 92-500 and Public Law 95-217 (The Clean Water Act of 1977) have focused attention on wastewater treatment. Stringent discharge requirements and the national goal of zero pollutant discharge will result in further massive cleanup of industrial and municipal effluents.

Dr. McCoy is with the Office of Water Research and Technology, Department of Interior, Wash., D.C. 20240.



SOURCE: G. M. Wesner - Published by Culp-Wesner-Culp, Santa Ana, California. February, 1978.
Fig. 1



This jungle of reverse osmosis technology can remove many kinds of contaminants from water with relatively low expenditures of chemicals and energy. (OWRT)

Water problems in other parts of the world are even more severe. The Middle East, for example, while rich in petroleum, is deficient in naturally occurring fresh water. Other areas needing water include Mexico, the Caribbean, North Africa, Spain, and Japan.

Because of these water shortages and pollution problems, experts estimate a substantial U.S. need, and thereby a desalting market for over 29 billion gallons per day (BGD) by the year 2000. Most would be used for cleanup and reuse, but about 3 BGD would be used for production of drinking water. By the same year, the foreign desalting market is expected to reach 5.5 BGD.

The effectiveness of each desalting process depends on site characteristics such as location, energy and its availability, feedwater type (input), and available brine disposal methods. Although no single process is most desirable for all locations and conditions, Fig. 1 shows the general acceptance range of effectiveness for various processes. The broken lines extending electrodialysis and reverse osmosis toward acceptability of water containing over 35,000 parts per million (ppm) dissolved solids reflect recent advances being achieved or anticipated in membrane technology. Distillation is the most commonly used process for large-scale seawater desalting. Freezing, while not commercially used at this time, has potential for low cost seawater desalting and wastewater concentration. For brackish water with less than 10,000 ppm dissolved minerals, reverse osmosis (RO) and electrodialysis (ED) offer economical methods for producing potable water.

Distilleries for making water have existed for centuries, though their uses have been limited. Distillation today produces nearly 78 percent of the world's desalted water. In distillation, saltwater is boiled to produce water vapor. The vapor condenses to form pure water, leaving the brine behind. Heat energy must be added to vaporize the water, and then removed to condense the stream into fresh water.

Distillation

Several types of distillation processes are in use. One of the most common is multi-stage flash distillation. (Fig. 2. All figures, unless otherwise noted, are courtesy of OWRT.) In this system, heated seawater is channeled into a low-pressure chamber. Because at lower pressures water boils at lower temperatures, some of the water in the chamber boils instantly or "flashes" into steam. Vaporization of water lowers the temperature of the remaining brine. This brine then flows into the next chamber where the pressure is even lower than in the previous chamber. Most water flashes into steam, and again, the temperature is reduced. The steam flashed from the brine condenses on the outside of the tubes and heats incoming seawater. Inside the tubes, seawater flows through the flash chambers from the low temperature end to the high temperature end of the plant and receives its final heat from a boiler prior to entering the highest pressure flash chamber. This continuous cycle makes maximum use of the energy supplied to the process.

Most of the processes have corrosion and scaling problems which decrease the systems' efficiency. Scale forms on the heat transfer surfaces in distillation plants

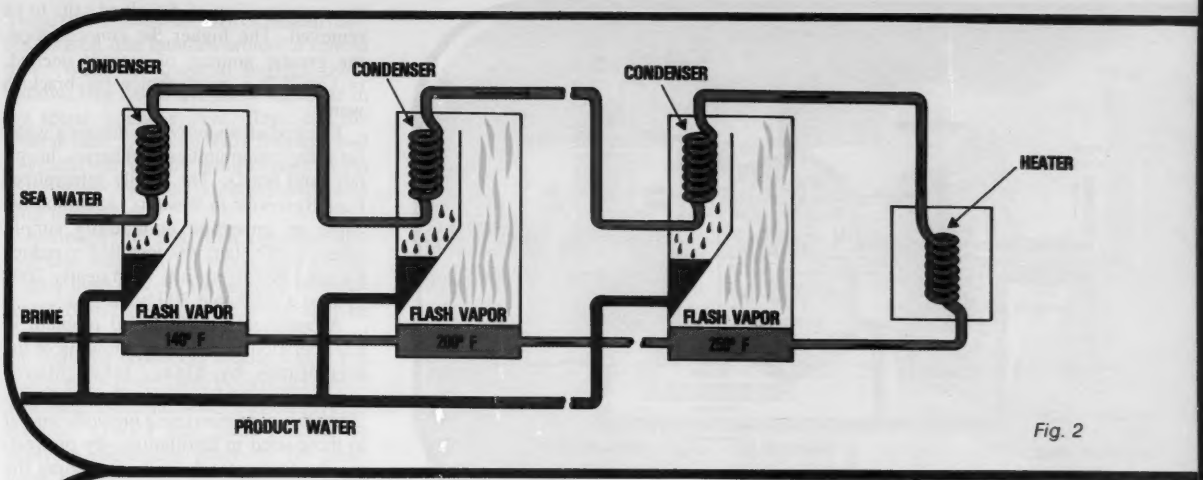


Fig. 2

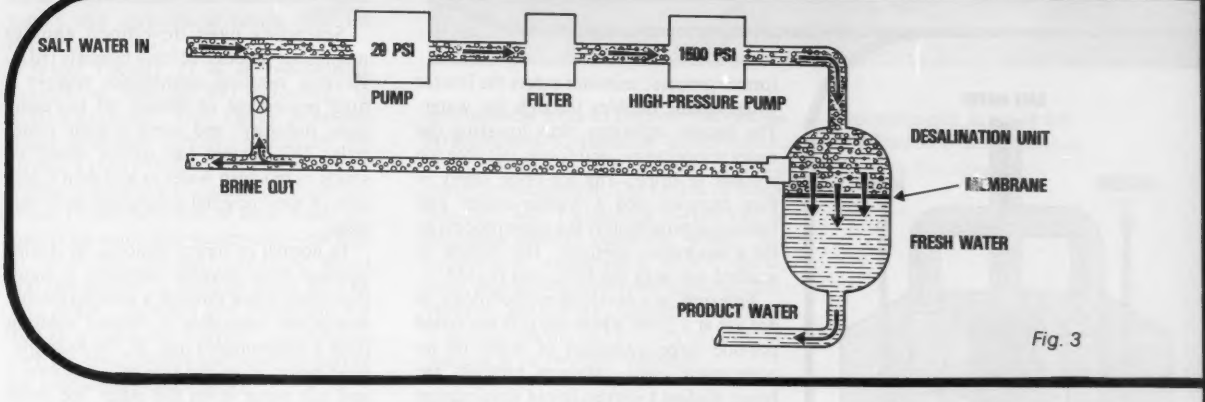


Fig. 3

as a result of deposition of compounds of calcium and manganese, silica, iron and other mineral salts, while fouling is usually caused by bacterial growth and organic material. Engineers regularly add chlorine to the feedwater to reduce growth and add a weak acid or other scale-inhibiting substances to decrease scaling. Calcium sulfate, immune to acid treatment and having retrograde solubility with temperature, is the most serious scaler.

Freezing

Cooling salt water low enough to form ice crystals is the basis for desalting by freezing. All freeze processes involve three major steps: partial freezing of feedwater into an ice-slurry, separating ice crystals from the brine, and melting the ice. In principle, this approach has noteworthy advantages over other methods. Low temperatures minimize corrosion and fouling, and freezing requires less thermal energy than other processes.

The freezing process desalts either by flash-evaporation of seawater at low pressures or by vaporizing a refrigerant such as butane in direct contact with seawater. In the first, deaerated water is cooled by heat exchange with product water and brine streams. (Fig. 3) This cold water then flows into a low-pressure chamber. The low pressure causes some of the water to vaporize, thus removing heat from the seawater. The seawater freezes into crystals of pure water; the remaining solution becomes a more concentrated brine. This mixture of ice crystals and brine flows into a separation column and the ice floats to the top where it is taken off. The ice is transferred to melters to produce fresh water.

The refrigerant process differs from the evaporation process principally in the method used to freeze the seawater. In the

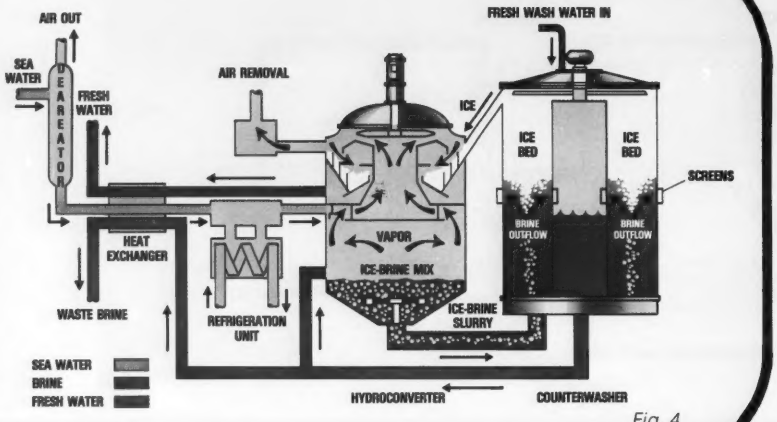


Fig. 4

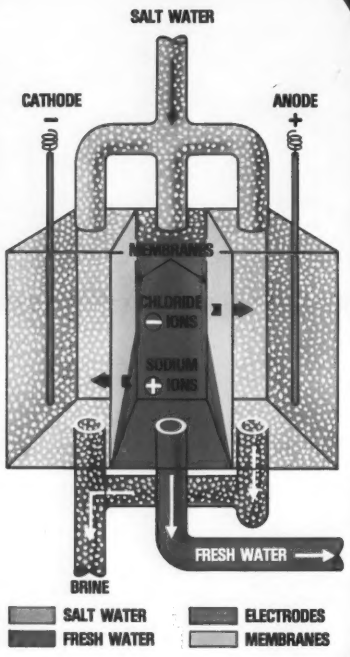


Fig. 5

former process, seawater enters the freezer when butane bubbles through the water. The butane vaporizes, thus lowering the water temperature, and forms salt-free ice crystals in brine. The ice-brine slurry is then pumped into a washer-melter and follows approximately the same process as the evaporation method. The butane is washed out with the brine and reused.

Freezing, as a desalting methodology, is not yet at a point where the process could provide large quantities of water on an economical basis, although methods are being studied to bring freeze desalination to a more competitive level. A special circumstance for freeze desalting would utilize waste heat, or "cold BTUs" such as are available when liquified natural gas is vaporized.

Electrodialysis

Electrodialysis (ED), one of the two membrane desalting processes, is used to desalt brackish water. This system is essentially a cell pair containing two different types of ion-selective membranes—one allowing passage of positive ions such as sodium, the other allowing passage of negative ions such as chloride—leaving fresh water between the membranes. Direct current provides the force which causes the ions to migrate through the membranes. (Fig. 4)

An ED unit contains many sets of membranes between the electrodes, and the amount of electric current required depends on both the number of cell pairs and the concentration of dissolved salts to be removed. The higher the concentration, the greater amount of current needed, making ED a good choice for brackish water.

Electrodialysis provides drinking water for many communities, industries, hospitals, and hotels. The highly mineralized Foss Reservoir in western Oklahoma became an important community supply when an ED plant was installed to reduce the total dissolved salts from nearly 2000 ppm to a drinkable 300 ppm.

A commonly encountered problem in ED operation is scaling and fouling of the membranes by algae, other microorganisms, and dissolved salts. Engineers offset this condition using methods similar to those used in distillation—by pretreating the feedwater or by backwashing the system.

Scientists have developed another membrane process: reverse osmosis (RO). Reverse osmosis membranes remove a high percentage of almost all inorganic ions, turbidity, and some organic materials. This system can reduce dissolved solids in brackish water to less than 1 percent of their original concentration in one stage.

In normal or direct osmosis, as distinguished from reverse osmosis, a water flow takes place through a semipermeable membrane separating a diluted solution from a concentrated one. If, for example, fresh water is on one side of a membrane and salt water is on the other, the fresh water flows through the membrane to dilute the salt water. However, by applying pressure to the salt water side, the process is reversed. Fresh water flows through the membrane through the salty side leaving a saltier solution behind. (Fig. 5)

Salt water first passes through a filter to remove suspended solids. The water, now under pressure, then flows into the desalination unit where the high pressure forces a portion of water through the membrane. Fresh water collects at the bottom of the unit, while the waste brine is discharged at the top.

Two types of membrane techniques are commonly used in RO. The first technique, spiral wound, uses large plastic sheets which are stacked together, then rolled up into a "log." The salt water is squeezed through the series of sheets, with fresh water flowing out through a tube in the center of the log. The other technique uses tiny, hollow, thin, synthetic fibers.

These fibers, about the size of human hair, are formed into bundles around a central tube. Water is squeezed through these hollow, fine fibers and fresh water, as in the spiral wound system, flows out the central tube. As with ED, fouling, and degradation of the membranes from chlorine are common problems associated with this process.

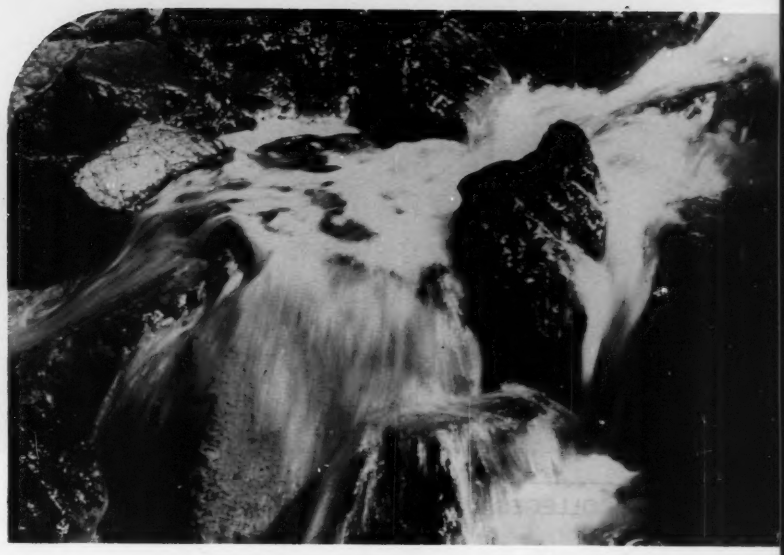
Although ED has been commercially available longer, RO is becoming the more widely used process for treating brackish water. Both processes are continuing to be developed and are being increasingly used not only for producing usable water, but also to recover valuable by-products, such as metals, from industrial wastewaters. In addition, OWRT sees great potential in applying membrane processes for treatment of municipal and industrial waste waters and agricultural return flow for reuse and recycling.

Water Factory 21 is an outstanding example of utilizing RO technology to treat wastewater. This highly advanced water treatment facility, owned by the Orange County Water District at Fountain Valley, California, is capable of producing about 17,000 acre feet of fresh water per year from municipal wastewater—enough to meet the personal needs of about 200,000 people or a city of about 50,000. This water is pumped into the ground for use as a saltwater barrier, commingles with the groundwater and becomes part of the municipal water supply.

All desalting processes generate concentrated brine as wastes. Engineers use a variety of methods to dispose of the waste, depending on the type of plant and site, not the least concern being compliance with environmental laws. Waste brine at ocean sites usually returns to the ocean, while inland disposal is a problem undergoing study. Evaporation ponds and deep well injection are being used, but continuation of these methods in the future will be very selective.

Before any desalting technologies can become more widely applicable, additional research and development is needed. Desalting developers have made significant progress since the early fifties, evidenced by increasing worldwide sales of desalting plants each year. As of 1977, about 1500 land-based desalting plants of 25,000 GPD, or larger capacity, were operated or under construction throughout the world.

Aided by the Federal government, in particular OWRT, current research and development aims to improve membrane effectiveness to increase performance, improving fouling resistance and reducing energy consumption. The Office of Water Research and Technology carries out its programs through contracts, grants, and cooperative agreements with Federal, state, and local government agencies, universities and private companies, although it does the testing and piloting of its development at its two test facilities.



Desalting can assist in the purification of water such as flows in this stream.

None of the viable means for augmenting water supply is quick, easy or cheap; none will make the desert bloom by next Thursday; none can be properly characterized as a quick-fix panacea, as has been done by otherwise well-informed persons in the case of desalting. No more reason exists for us to be satisfied with the present status of desalination technology than with the present status of national defense or national health; and since not even the best conceivable conservation and management can ultimately solve all present and future water problems, special consideration should be given to the virtually unlimited potential sources of brackish and seawater. We can confidently look forward to the time when desalting will produce many billions of dollars of fresh water every day in the quality and quantity required for agriculture, industry and by people, at locations they select—and most important, at prices they can afford. ■

Events, Deeds & Deliberations

COLLEGES & CORPS.=CONSORTIUM

by Betty M. White

What do square dancing, a fish hatchery, a leisurely boat ride on the Missouri River, and the Army Corps of Engineers have to do with earning college credits?

They were all part of the first Missouri River Lakes Consortium, held at Lewis and Clark Lake near Yankton, S.D. Co-sponsored by the University of Nebraska-Lincoln; Western Illinois University; and the Omaha District of the Army Corps of Engineers, 41 college students in the recreation-resource management field participated in the consortium.

"Too many educators maintain the limited concept that learning can only take place in the classroom," said Dr. Rick Bunch, Chairman of the Department of Recreation and Park Administration at Western Illinois University and Business Manager of the consortium.

"What we've done here is bring together students and a variety of resources, both human and natural, in a way that could never happen in a traditional classroom setting." Bunch continued.

Dr. Bill Murphy, Chairman of the Department of Recreation and Leisure Studies at the University of Nebraska-Lincoln and Dean of the Consortium, said, "We just think this is a super experience for our kids. . . a chance to get together with professionals and hear firsthand about the careers many of these students would like to pursue.

"It's got to mean more coming from a professional out here than coming from a teacher in a classroom," he continued, "even if we're both telling the students the same things."

Dale Crane, a staff consultant for the U.S. House of Representatives Subcommittee on National Parks and Insular Affairs, opened the consortium with the keynote address at Mount Marty College in Yankton, where the group boarded during their six-day stay.

Drawing on his experiences as the former Chief of the Recreation-Resources Management Branch, Operations Division, Directorate of Civil Works, U.S. Army Corps of Engineers, Crane explained the success of Corps projects by noting that "people find the association between water and land to be precisely what they want for recreation."

In citing the growth of the Corps over the past decade, Crane asked, "Where is the Corps going now? I think it's going up," he answered. "I see no reason why it should go down. The Corps has been so successful because of its diversity of resources," Crane continued.

He urged the students to gain a knowledge of politics, computers, and business management, all of which will be useful to them in their parks and recreation careers, he said.

Along these same lines, Col. James W. Ray, Omaha District Engineer at the time of the consortium, encouraged the students to take any courses they could in contract administration, and to learn about and take the PACE civil service test. Col. Ray welcomed the students to the consortium with a brief message, concluding with: "Your agenda seems too much in too short a time . . . but have a good time anyway."

Perhaps those participants who did not view Col. Ray's message as an omen should have, for over the next five days they attended more than 30 presentations representing a wide range of recreation-resource management topics.

From fishery research and a tour of the Gavins Point National Fish Hatchery to campground design, from recreational access for the handicapped to lakeshore and streambank erosion, the presentations, according to one student, sometimes seemed "as if they'd never end."

In defense of the rigourous schedule, Dr. Bunch said, "We've traveled a long way to come up here, and we might as well take advantage of everything while we're

Betty White is in the Public Affairs Office, Omaha District, U.S. Army Corps of Engineers, Omaha, Nebraska 68102.

here—even if it burns us out. We can always recuperate." Another reason for the demanding agenda was that students received two academic credits for participating. This included required written work.

The concept of the consortium, which is aimed at giving actual field experience to students in the recreation-resource management field, is brand new to the Corps. The Tennessee Valley Authority is the only other large organization currently involved in similar projects.

Blaine Cunningham of the Omaha District's Recreation-Resource Management Branch, coordinated the consortium from the Corps' end. "We consulted with Dick Cottrell and his staff at TVA and received a great deal of valuable advice," Cunningham explained. "We adopted some of their techniques, adapted others, and developed some of our own."

"The TVA consortiums (held at Land Between the Lakes) have tended to hit the recreation area harder than we did," Cunningham noted. "We spent more time on the resource management. But I would view our program as complementary to that of the TVA, rather than competitive."

Both Dr. Bunch and Dr. Murphy expressed their appreciation of the Corps' efforts in making the consortium the success it was. "The Corps did an excellent job in pulling together the resources we were looking for," Bunch said.

But what about the students? What did they think of the consortium?

Herb Anderson, a junior recreation major from Nebraska-Lincoln, was very favorable toward the opportunity to experience firsthand some of the problems involved in park management. He cited a panel discussion on interagency relationships as being particularly valuable. Another presentation consistently cited by the students as being among the best was an overview of interpretive

The group during their visit to the Gavins Point National Fish Hatchery.

services by Jeanne Minahan of the Omaha District's Recreation-Resource Management Branch. Minahan stressed the need for providing ways for the public to experience points of interest during their visit to a park, as opposed to simply being told about them. As an example, she called for volunteers to form a "living dam," where people actually form a dam to hold back the water (as played by other people). "It's an excellent interpretive technique to help people understand how dams work," she explained.

She also expressed a desire for the Corps to develop "water trails" as a way of interpreting its water resources. This is because "forest and land resources are currently being interpreted by other agencies," she explained. The

participants reacted positively to the fact that the flow of information at the consortium was not limited solely to the traditional teacher-to-student. On several occasions the students were asked for input on problems that had the professionals genuinely stumped.

Bob Nebel of the Omaha District's Planning Division, for example, asked the participants if they could offer any suggestions on how to keep motorcycles out of an unmanned Corps recreation project while at the same time insuring that this area will be easily accessible to those confined to wheelchairs. Several possible solutions to this problem were offered by the students, including one suggestion of a card-key system. Said a Western Illinois coed, "It meant a lot to me to see these professionals actually soliciting our opinions."

An all-day field trip around Lewis and Clark Lake was also popular among the participants. The 80-mile trip was highlighted by a ferry ride across the Missouri River at Springfield, S.D. The operator of the ferry, Captain Mick May, spent a few minutes at the conclusion of the crossing to briefly describe his unique operation. May's ferry is one of the last of its kind, and visitors have come from around the world to take the 20-minute river crossing.

At the conclusion of the final presentation each evening, the group gathered for athletic and social activities. Aside from the more traditional volleyball, frisbee throwing, and square dancing, "New Games" were also played. "New Games" are non-competitive athletic events where there is no elimination and, quite frequently, no winner or loser. The games, such as untying elaborate human knots, were quite useful in helping the students get to know each other.

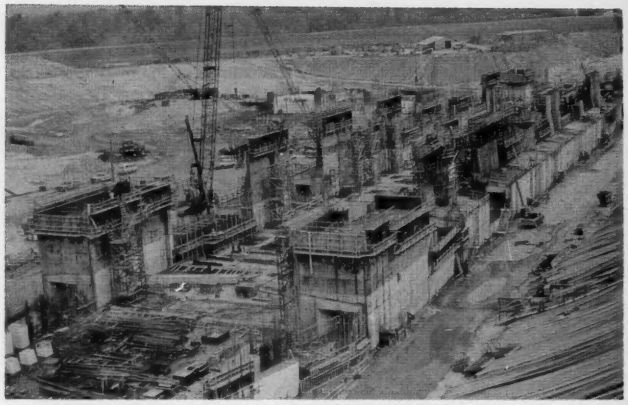
Perhaps the greatest benefit of the consortium—repeatedly cited by the students, faculty, and Corps personnel alike—was the opportunity to get together and share knowledge, experiences, and friendships.

"The chance to meet new people, learn about the recreation programs at other schools, and exchange ideas with professionals is what this consortium was all about," said Doug McCallum, a Nebraska-Lincoln faculty member. "And, who knows," McCallum continued, "this just may open some career doors for some of the participants."

Regarding additional consortium projects in the future, Col. V.D. Stipo, newly assigned Omaha District Engineer in June, said "I think this is a good area for the Corps to get involved in. . . We'll certainly have to consider the possibility of similar projects in the future." ■

ARKANSAS IMPROVEMENTS READIED

A new system of locks and dams, under construction by the Army Corps of Engineers in Arkansas, is expected to provide that state with a more efficient avenue for putting its goods on the national and world markets. The system will extend the basin's domestic market range by nearly 1500 miles, and will replace an antiquated series of six locks and dams constructed more than 50 years ago. As tows have become larger, the shippers have turned away from use of the Arkansas' current 6-foot navigation channel. It is anticipated, however, that within three to five years southern Arkansas will again be competitive in the waterborne commerce arena, and able to move the products of the Ouachita River area on a large scale. Two locks are being built at Huttig and Calion in the state's south central region, which, when completed, will join finished locks at Columbia and Jonesville, Louisiana, in linking Camden, Arkansas, with the Mississippi River 400 miles away. ■



Felsenthal lock and dam, on the new Ouachita-Black Navigation System, rises from the Arkansas landscape. The new lock and dam will measure 600 feet by 84 feet wide, about twice as large as the obsolete structure it replaces. (Vicksburg District, CofE Photo)

NPS MODEL TESTED IN HONEY CREEK BASIN

Application of a land management model to a large agricultural watershed in the Great Lakes region is described in a report published recently by the U.S. Environmental Protection Agency's Environmental Research Laboratory in Athens, Georgia. The study revealed advantages and limitations of EPA's Nonpoint Source Model as a tool for estimating reductions of pollution from agricultural land.

In the year-long study, the model's hydrological and chemical routing equations produced a satisfactory simulation of the Honey Creek watershed, a segment of the Lake Erie drainage basin. The simulations, however, masked many important but subtle processes that must be understood to improve the model as a technique for land management analysis.

The report, *"Nonpoint Source Model Calibration in Honey Creek Watershed,"* (EPA-600/3-79-054) was written by T. H. Cahill, R. W. Pierson, Jr., and B. R. Cohen of Research Management Associates, West Chester, PA. Project officer for the study, which was performed under EPA grant, was Tom Barnwell of the Athens Laboratory's Technology Development and Applications Branch. It is available from the Environmental Research Laboratory, USEPA, College Station Road, Athens, GA 30605. ■

COMSAT TO OPERATE WATER INFORMATION SERVICE

A $2.2 million contract has been awarded to the COMSAT General Corporation by the U.S. Geological Survey, Department of the Interior, to set up a pilot program for a communications satellite-supported water information service, Interior Secretary Cecil D. Andrus has announced.

The pilot program will test the feasibility of establishing a full-scale system of collecting hydrologic data such as stream stages and water quality from USGS water monitoring stations and, in almost instantaneous fashion, transmitting the data to receiving stations by commercial satellites.■

Coming Events

May 1980—Symposium on Unified River Basin Management at Gatlingburg, Tennessee.

May 19-22, 1980—23rd Conference on Great Lakes Research at Queen's University, Kingston, Ohio.

May 19-23, 1980—Third International Conference on Finite Elements in Water Resources at the University of Mississippi.

May 28-31, 1980—Symposium on Water and Related Land Resource Systems at Case Western Reserve University, Cleveland, Ohio.

June 2-4, 1980—Symposium on Surface-Water Impoundments, ASCE, Minneapolis, Minnesota.

June 15-19, 1980—Annual Conference of the Outdoor Writers Association of America, at the Howard Johnson's Motor Lodge in Rapid City, South Dakota.■

Bookshelf

Biological Surveillance of Rivers: A Biological Monitoring Handbook by J. M. Hellawell is written for biologists concerned with river quality. The book intends to serve as a guide to more comprehensive treatments of specific aspects of freshwater biology. It is available from the Water Research Center, Medmenham Laboratory, P.O. Box 16, Henley Road, Medmenham, Marlow, Buckinghamshire, SL7 2HD, England.

Planning the Total Landscape: A Guide to Intelligent Land Use by Julius Gy. Fabos, identifies and explains ways to minimize potential undesirable effects of land development. These methods can include modern techniques, such as remote sensing, statistical analysis, and computer technology. The book is available from the Westview Press, 5800 Central Avenue, Boulder, Colorado 80301 for $16.

An Atlas of the Biological Resources of the Hudson Estuary is a 104-page paperback put together by a team of scientists from the non-profit Boyce Thompson Institute. It describes the interactions of many different species of plants and animals, and features descriptions and accurate drawings of the major plants, fishes, and other species. Seasonal changes and interactions among species are clearly explained in text and diagrams. The *Atlas* is distributed by the Publishing Center for Cultural Resources, 152 West 42 Street, New York City, 10036 for $5.50.

Measurement of Organic Pollutants in Water and Wastewater by C. E. Van Hall provides a forum for scientists engaged in the development and practice of analytical methodology for the organic priority pollutants. It can be obtained from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania for $36.50, Publication Code No.: 04-686000-16.■

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Just how dependent is man upon estuaries—such as this one at Great South Bay, New York—and estuaries upon man? *See "The Estuary Revisited" on Page 1.*